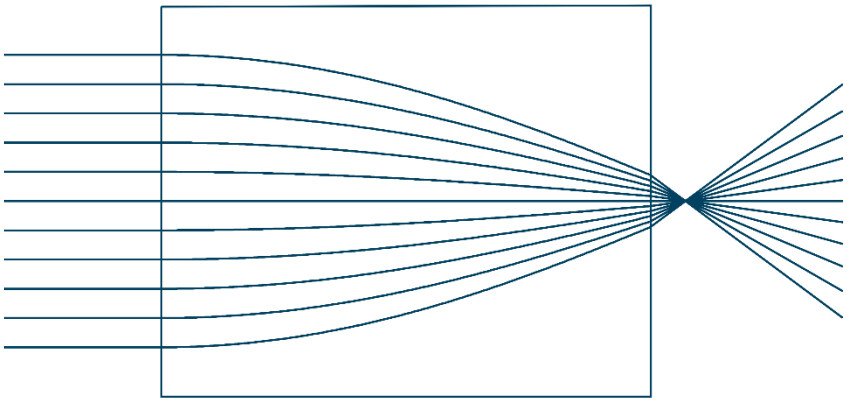
GRINTECH GmbH



product information

www.grintech.de

Directory

The Company

GRINTECH is one of the leading manufacturers of gradient index (GRIN) micro-optic lenses and lens systems based on more than 20-years of experience.

GRINTECH delivers medical imaging and biophotonic technology, optical metrology and sensor technology to growing markets.

GRIN-lenses are miniaturized lenses having extraordinary good optical performance and flat optical surfaces.

The optical power of GRIN-lenses is achieved by a refractive index (GRadient INdex) profile fabricated by a non-toxic silver or lithium ion exchange process in glass. Our unique rod micro lenses have typical dimensions from 250 μm to 2 mm.

With diffraction-limited numerical apertures up to 0.45, the flat optical surfaces enable an easy assembly to micro-optical lens systems tailored to your specific requirements. Our products consist not only of GRIN lenses, but integrate where necessary also other micro lenses, optical fibers, prisms, filters, beam splitters and mechanical mounts to robust modules.

GRINTECH GmbH was founded in 1999 as a spin-off of the Fraunhofer Institute for Applied Optics and Precision Engineering in Jena, Germany. From the end of 2021, our new company facility will offer us a doubling of work space, a great step in GRINTECH's history to inspire our creativity and your future needs.

We at GRINTECH support the GRIN technology with our long-standing technical expertise and reliable customer service.

Scope of Business

In the view of our worldwide customers, GRINTECH is well known as a highly flexible development and fabrication partner for special customer driven and adapted micro-optomechanical modules. These assemblies and subassemblies are often inspired by or based on our **standard products**, which are presented in the following catalogue section (page 3 – 15). They range from GRIN rods used for fiber and laser diode collimation and beam shaping (page 3 - 5) over lenses and assemblies for clinical and industrial endoscopic applications (page 6 - 7) up to needle imaging assemblies and miniature high-NA objectives for in-vivo endomicroscopy and related accessories (page 9 - 16).

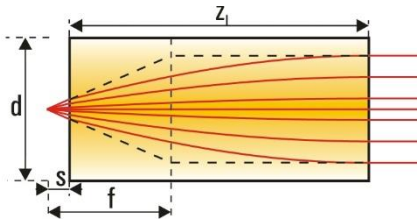
However, most successfully our customers appreciate that GRINTECH develops, fabricates and delivers custom-made modules and assemblies dedicated to the specific needs of their application with a high quality and reliability. For the research market, that is impressively illustrated by the **publication list** of our customers using GRINTECH optics on our website, often in world leading scientific journals.

Further more, we also support our industrial customers with our sophisticated team of several optical designers and mechanical engineers to design and produce, beyond the standard catalogue products, much more complex optical sensors, focussing or deflecting modules and imaging assemblies consisting of mechanical housings and mounts, optical fibers, prisms, beam splitters, laser diodes etc., which are combined with GRIN and other lenses. We invite you to complete the **custom assembly configurator** on pages 21 - 25 to make the communication process as fast, efficient and easy as possible. It helps to clarify the most popular features, as for example fiber type, length, buffer, connector type, prism size, stainless steel tube mounts, angled fiber end face, coatings, design wavelengths, spot or image working distance, spot size and numerical aperture, etc., and to add your specific requested features.

You can find the same content also on www.grintech.de for contact to our sales and engineering team.

Please explore and get inspired!

GRIN Rod Lenses – Numerical Aperture 0.5



Gradient index lenses for fiber coupling and beam shaping of laser diodes

Diameter (mm)	Pitch P	Working distance s (mm)	Lens length z_l (mm)	Focal length f (mm)	Gradient constant g (mm^{-1})	Refractive index at the center of the profile n_0	Wavelength λ (nm)	Product code
0.50	0.25	0	1.15	0.45	1.369 - 1.349*	1.629 - 1.616*	670-1550	GT-LFRL-050-025-50-NC
	0.23	0.06	1.05	0.46	1.369 - 1.349*	1.629 - 1.616*	670-1550	GT-LFRL-050-023-50-NC
1.00	0.25	0	2.25	0.88	0.697	1.629	670	GT-LFRL-100-025-50-NC (670)
	0.25	0	2.27	0.89	0.693	1.624	810	GT-LFRL-100-025-50-NC (810)
	0.25	0	2.29	0.90	0.687	1.616	1550	GT-LFRL-100-025-50-NC (1550)
	0.23	0.12 - 0.11*	2.06	0.90	0.697 - 0.687*	1.629 - 1.616*	670 - 1550	GT-LFRL-100-023-50-NC
1.80	0.25	0	4.24	1.66	0.370	1.629	670	GT-LFRL-180-025-50-NC (670)*
	0.25	0	4.27	1.67	0.368	1.624	810	GT-LFRL-180-025-50-NC (810)
	0.25	0	4.30	1.70	0.365	1.616	1550	GT-LFRL-180-025-50-NC (1550)
	0.23	0.25 - 0.21*	3.88	1.69	0.370 - 0.365*	1.629 - 1.616*	670 - 1550	GT-LFRL-180-023-50-NC
2.00	0.25	0	4.85	1.89	0.324	1.629	670	GT-LFRL-200-025-50-NC (670)*
	0.25	0	4.88	1.91	0.322	1.624	810	GT-LFRL-200-025-50-NC (810)
	0.25	0	4.92	1.94	0.319	1.616	1550	GT-LFRL-200-025-50-NC (1550)
	0.23	0.27 - 0.23*	4.45	1.93	0.324 - 0,319*	1.629 - 1.616*	670 - 1550	GT-LFRL-200-023-50-NC

*: depending on wavelength

- Working distance, design wavelength and lens length deviating from these standards are available on request
- 8° angled facet / other diameters (0.25 mm, 0.35 mm, 0.60 mm and 0.85 mm) are available on request
- ZEMAX files can be DOWNLOADed from our website
- For tolerances, handling and storage see page 26

GRIN rod lenses are offered without antireflection coatings as standard. Antireflection coatings (R < 1.0 % for the design wavelength and incidence angles of 0 ... 30° corresponding to measurements on a reference substrate) can be offered:

Coating Code:
- NC: no coating (reflection loss approx. 12 %) - standard
- C1: λ = 450 ... 690 nm
- C2: λ = 800 ... 1000 nm
- C5: λ = 1310 ... 1550 nm

One - sided coatings are available on request.

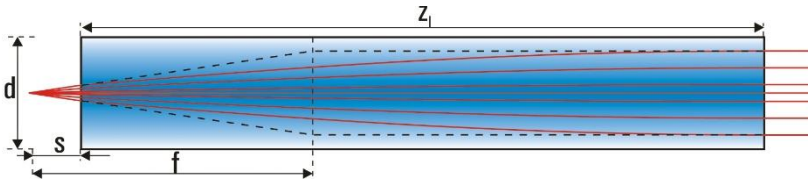
Order example:

GT – LFRL – 100 – 025 – 50 – NC – (670)	
GT	GRINTECH
LFRL	Focusing Rod Lens
100	Diameter: 0.5, 1.0, 1.8 or 2.0 mm
025	Pitch: 0.25 or 0.23
50	NA: 0.50
NC	Coating Code: NC, C1, C2 or C5
(670)	Design Wavelength

Variations due to modifications of the production process are possible. It is the user´s responsibility to determine suitability for the user´s purpose.

* Please note our partnership with Inscopix as our exclusive distributor for the field of neuroscience applications in non-humans (see page 8).

GRIN Rod Lenses – Numerical Aperture 0.2



Gradient index lenses for fiber coupling and beam shaping of laser diodes

Diameter (mm)	Pitch P	Working distance s (mm)	Numerical Aperture NA	Lens length z_I (mm)	Focal length f (mm)	Gradient constant g (mm^{-1})	Refractive index at the center of the profile n_0	Wavelength λ (nm)	Product code
0.50	0.25	0	0.20	3.05	1.28	0.515	1.524	670	GT-LFRL-050-025-20-NC (670)
	0.25	0	0.20	3.06	1.28	0.513	1.521	810	GT-LFRL-050-025-20-NC (810)
	0.25	0	0.20	3.07	1.29	0.511	1.515	1550	GT-LFRL-050-025-20-NC (1550)
	0.24	0.09 – 0.07*	0.20	2.94	1.28	0.515 - 0.511*	1.524 - 1.515*	670 - 1550	GT-LFRL-050-024-20-NC
1.00	0.25	0	0.20	6.12	2.56	0.257	1.524	670	GT-LFRL-100-025-20-NC (670)
	0.25	0	0.20	6.13	2.57	0.256	1.521	810	GT-LFRL-100-025-20-NC (810)
	0.25	0	0.20	6.16	2.59	0.255	1.515	1550	GT-LFRL-100-025-20-NC (1550)
	0.24	0.18 - 0.15*	0.20	5.89	2.57	0.257 - 0.255*	1.524 - 1.515*	670 - 1550	GT-LFRL-100-024-20-NC
1.80	0.25	0	0.20	11.15	4.66	0.141	1.524	670	GT-LFRL-180-025-20-NC (670)
	0.25	0	0.20	11.17	4.68	0.140	1.521	810	GT-LFRL-180-025-20-NC (810)
	0.25	0	0.20	11.22	4.72	0.139	1.515	1550	GT-LFRL-180-025-20-NC (1550)
	0.24	0.31 - 0.26	0.20	10.74	4.68	0.141 - 0.139*	1.524 - 1.515*	670 - 1550	GT-LFRL-180-024-20-NC

*: depending on wavelength

- Working distance, design wavelength and lens length deviating from these standards are available on request
- other diameters (0.25 mm and 0.35 mm) are available on request
- ZEMAX files can be DOWNLOADed from our website
- For tolerances, handling and storage see page 26

GRIN rod lenses are offered without antireflection coatings as standard.
Antireflection coatings (R < 1.0 % for the design wavelength and incidence angles of 0 ... 10° corresponding to measurements on a reference substrate) can be offered:

Coating Code:
- NC: no coating (reflection loss approx. 12 %) - standard
- C1: λ = 450 ... 690 nm
- C2: λ = 800 ... 1000 nm
- C5: λ = 1310 ... 1550 nm

One - sided coatings are available on request.

Order example:

GT – LFRL – 100 – 025 – 20 – NC – (670)	
GT	GRINTECH
LFRL	Focusing Rod Lens
100	Diameter: 0.5, 1.0, 1.8 mm
025	Pitch: 0.25 or 0.24
20	NA: 0.20
NC	Coating Code: NC, C1, C2 or C5
(670)	Design Wavelength

Variations due to modifications of the production process are possible. It is the user´s responsibility to determine suitability for the user´s purpose.

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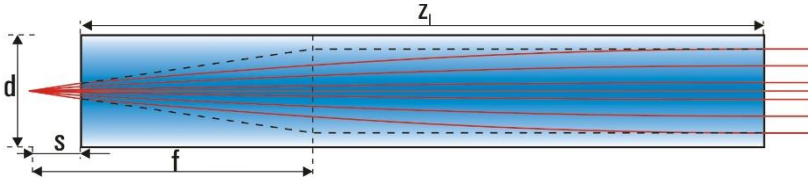
GRIN Rod Lenses – Numerical Aperture 0.2 – for high-performance collimation

with optimized gradient index profile for compensation of higher-order spherical aberrations and better beam quality



Gradient index lenses for fiber coupling and beam shaping of laser diodes

Diameter (mm)	Pitch P	Working distance s (mm)	Numerical Aperture NA	Lens length z_l (mm)	Focal length f (mm)	Gradient constant g (mm^{-1})	Refractive index at the center of the profile n_0	Wavelength λ (nm)	Product code
1.00	0.25	0	0.20	6.04	2.52	0.260	1.524	670	GT-CFRL-100-025-20-NC (670)
	0.25	0	0.20	6.05	2.53	0.260	1.521	810	GT-CFRL-100-025-20-NC (810)
	0.25	0	0.19	6.08	2.55	0.258	1.515	1550	GT-CFRL-100-025-20-NC (1550)
	0.24	0.18 - 0.16*	0.19	5.81	2.54	0.258 - 0.260*	1.524 - 1.515*	670 -1550	GT-CFRL-100-024-20-NC (1550)
1.80	0.25	0	0.19	11.06	4.62	0.142	1.524	670	GT-CFRL-180-025-20-NC (670)
	0.25	0	0.19	11.08	4.64	0.142	1.521	810	GT-CFRL-180-025-20-NC (810)
	0.25	0	0.19	11.13	4.68	0.141	1.515	1550	GT-CFRL-180-025-20-NC (1550)
	0.24	0.31 - 0.26*	0.19	10.71	4.69	0.142 - 0.141*	1.524 - 1.515*	670 -1550	GT-CFRL-180-024-20-NC (1550)

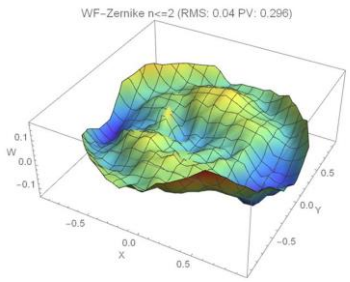
*: depending on wavelength

- Working distance, design wavelength and lens length deviating from these standards are available on request
- ZEMAX files can be DOWNLOADed from our website
- For tolerances, handling and storage see page 26

optimized

- **Wavefront RMS @ 635 nm < 0.07**
- diffraction limited properties
- higher order spherical aberrations are corrected
- for high-performance applications
  (e.g. collimators with M^2 < 1.1)

measured wavefront error: 0.055λ RMS



GRIN rod lenses are offered without antireflection coatings as standard. Antireflection coatings (R < 1.0 % for the design wavelength and incidence angles of 0 ... 30° corresponding to measurements on a reference substrate) can be offered:

Coating Code:
- NC: no coating (reflection loss approx. 12 %) - standard
- C1: λ = 450 ... 690 nm
- C2: λ = 800 ... 960 nm
- C5: λ = 1310 ... 1550 nm

One - sided coatings are available on request.

Order example:

GT – CFRL – 100 – 025 – 20 – NC – (670)	
GT	GRINTECH
CFRL	Focusing Rod Lens for high-performance collimation
100	Diameter: 1.0, 1.8 mm
025	Pitch: 0.25 or 0.24
20	NA: 0.20
NC	Coating Code: NC, C1, C2 or C5
(670)	Design Wavelength

Variations due to modifications of the production process are possible. It is the user´s responsibility to determine suitability for the user´s purpose.

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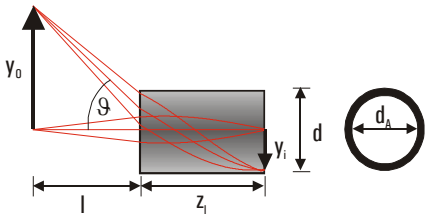
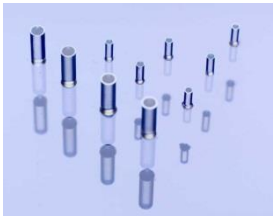
GRIN Objective Lenses for Endoscopy

- Gradient index lenses for endoscopic imaging optics
- Non-toxic silver-based glass material
- view angle $\vartheta = \pm 30°$
- Plane surfaces, low chromatic aberration
- Combination with prisms and beam splitter cubes on request
- Aperture and field stops (black chromium coating ring on lens surface generated by photolithography) are available on request
- Certification: Biological safety – toxicology (EN ISO 10993-1)
- Design wavelength: 570 nm





Diameter d (mm)	Working distance l (mm)	Lens length[1] z_l (mm)	Parax. Magnification $M = y_0/y_i$	Refractive index at the center of the profile n_0	Product code
2.0*	Infinity	4.79	--	1.635	GT-IFRL-200-inf-50-NC*
2.0	20	5.06	-10.78	1.635	GT-IFRL-200-020-50-NC
	10	5.33	-5.46	1.635	GT-IFRL-200-010-50-NC
	5	5.84	-2.86	1.635	GT-IFRL-200-005-50-NC
1.8*	Infinity	4.19	--	1.635	GT-IFRL-180-inf-50-NC*
1.8	20	4.40	-12.29	1.635	GT-IFRL-180-020-50-NC
	10	4.61	-6.21	1.635	GT-IFRL-180-010-50-NC
	5	5.01	-3.22	1.635	GT-IFRL-180-005-50-NC
1.0	Infinity	2.23	--	1.635	GT-IFRL-100-inf-50-NC
	20	2.29	-23.1	1.635	GT-IFRL-100-020-50-NC
	10	2.35	-11.58	1.635	GT-IFRL-100-010-50-NC
	5	2.46	-5.86	1.635	GT-IFRL-100-005-50-NC
0.85	Infinity	1.93	--	1.635	GT-IFRL-085-inf-50-NC
	10	2.02	-13.34	1.635	GT-IFRL-085-010-50-NC
	5	2.11	-6.73	1.635	GT-IFRL-085-005-50-NC
0.6	Infinity	1.32	--	1.635	GT-IFRL-060-inf-50-NC
	10	1.36	-19.48	1.635	GT-IFRL-060-010-50-NC
	5	1.40	-9.78	1.635	GT-IFRL-060-005-50-NC
0.5	Infinity	1.13	--	1.635	GT-IFRL-050-inf-50-NC
	10	1.16	-22.71	1.635	GT-IFRL-050-010-50-NC
	5	1.19	-11.39	1.635	GT-IFRL-050-005-50-NC
0.35	5	0.79	-16.9	1.635	GT-IFRL-035-005-50-NC
0.25	5	0.56	-23.63	1.635	GT-IFRL-025-005-50-NC

- Working distance and lens length deviating from these standards are available on request
- ZEMAX files can be DOWNLOADed from our website
- For tolerances, handling and storage see page 26

GRIN rod lenses are offered without antireflection coatings as standard. Antireflection coatings (R < 1.0 % for the design wavelength and incidence angles of 0 ... 30° corresponding to measurements on a reference substrate) can be offered:

Coating Code: NC: no coating (reflection loss approx. 12 %) - standard
C1: λ = 450 ... 690 nm

One - sided coatings are available on request.

Order example:

GT – IFRL – 100 – 010 – 50 – NC	
GT	GRINTECH
IFRL	Imaging Focusing Rod Lens
100	Diameter: 0.25, 0.35,0.5, 0.6, 0.85 1.0, 1.8 or 2.0 mm
010	Working distance: 5, 10, 20 mm or infinity
50	NA: 0.50
NC	Coating Code: NC or C1

Variations due to modifications of the production process are possible. It is the user´s responsibility to determine suitability for the user´s purpose.

Note: GRINTECH objective lenses can be combined with GRIN relay lenses to complete endoscopic imaging systems by gluing the optical surfaces directly together. Prisms to change the direction of view can also be glued directly on the front surface of the objective lens. We are happy to advise you.

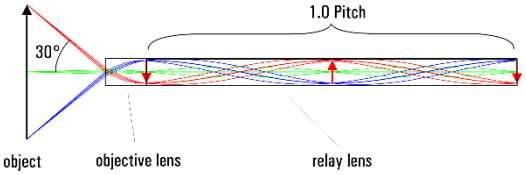
* Please note our partnership with Inscopix as our exclusive distributor for neuroscience applications in non-humans (see page 8).

GRIN Endoscopic Rod Lens Systems

GRIN endoscopic systems, which combine a GRIN objective lens, a GRIN relay lens and a GRIN eyepiece. Combining the system with a prism enables the change of the direction of view. Standard diameters are 0.35, 0.5, 1.0 und 2.0 mm. We offer the systems in two different principle design options:

Design A:
The objective lens creates a reduced intermediate image at the exit surface of the objective lens, which will be imaged by the relay lens 1:1 (if the lens length of the relay lens is a multiple of the period) or - 1:1 (if the lens length of the relay lens is an odd multiple of the half period) to the exit surface of the relay lens.

schematic view design A



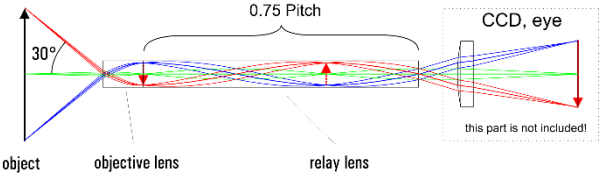
possible working distances (please specify):
0.35 mm diameter: 5 mm,
0.5 to 2.0 mm diameter: 5 mm, 10 mm and infinity
other working distances on request

possible pitch lengths:

diameter	Relay pitch	System length [mm]	Image orientation
0.35	0.5	approx. 8.2	inverted to like design A
	1.0	approx. 15.7	like design A
	1.5	approx. 23.1	inverted to like design A
0.50	0.5	approx. 16.3	inverted to like design A
	1.0	approx. 31.4	like design A
	1.5	approx. 46.5	inverted to like design A
1.00	0.5	approx. 24.7	inverted to like design A
	1.0	approx. 47.0	like design A
	1.5	approx. 69.4	inverted to like design A
2.00	0.5	approx. 55.5	inverted to like design A
	1.0	approx. 105.8	like design A
	1.5	approx. 156.0	inverted to like design A

Design B:
The objective lens creates a reduced intermediate image at the exit surface of the objective lens, which will be imaged by the relay lens at infinity. Such a lens system is a complete endoscopic imaging system. It allows the direct observation with the human eye or the use of a conventional camera system (including camera lens): camera and camera lens are not included!

schematic view design B

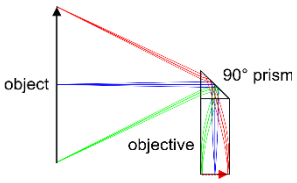


possible working distances (please specify):
0.35 mm diameter: 5 mm,
0.5 to 2.0 mm diameter: 5 mm, 10 mm and infinity
other working distances on request

possible pitch lengths:

diameter	Relay pitch	System length [mm]	Image orientation
0.35	0.75	approx. 12.0	like design B
	1.25	approx.19.4	inverted to like design B
	1.75	approx. 26.9	like design B
0.5	0.75	approx. 23.8	like design B
	1.25	approx.38.9	inverted to like design B
	1.75	approx. 54.0	like design B
1.00	0.75	approx. 35.9	like design B
	1.25	approx. 58.2	inverted to like design B
	1.75	approx. 80.6	like design B
2.00	0.75	approx. 80.7	like design B
	1.25	approx. 130.9	inverted to like design

Both versions are available with a 90° change of view by attaching a prism to the objective.



Order example:

GT – ERLS – d – wd – p	
GT	GRINTECH
ERLS	Endoscopic Rod Lens System
d	Diameter: 0.35, 0.50, 1.00 or 2.00 mm
wd	Working distance: 5, 10 mm or infinity
p	Relay pitch: 0.50, 0.75, 1.00, 1.25, 1.50 or 1.75

For tolerances, handling and storage see page 26

We are happy to advise you. Please contact us.

Extension of Partnership

Brain Imaging – one of the most enabling applications of GRINTECH micro optics

Endomicroscopy using GRINTECH lenses and assemblies allows an *in-vivo* imaging access to deep tissue regions in the brain, especially in non-humans. It helps to understand disease formation and progression on a cellular level of the tissue.

We are pleased to inform that GRINTECH GmbH has expanded its strategic partnership with Inscopix Inc. beyond one-photon imaging to include exclusively serving customers on behalf of GRINTECH in two-photon imaging and across all non-human neuroscience research applications.

Inscopix offers innovative products and scientific consulting services for advancing neuroscience research and we are excited to be able to partner with Inscopix to serve a broader research community. Inscopix commits to continuing to support legacy GRINTECH customers with their microendoscope imaging needs across all neuroscience preclinical imaging applications. Inscopix Field Scientific Consultants and Inscopix's Support team will now be available to all legacy GRINTECH customers and to any customer interested in leveraging microendoscope imaging for their brain research, irrespective of whether the user or lab is a customer of Inscopix instrumentation. The expanded partnership aims to benefit GRINTECH customers and the broader Neuroscience research community with a dedicated neuroscience partner, enhanced scientific support and customer service, and volume-based pricing discounts.

Going forward, Inscopix will be your primary contact for ordering GRIN lenses for non-human Neuroscience research applications. If you have a one-time, custom GRIN lens order, Inscopix will work with GRINTECH to ensure that if Inscopix is unable to fulfill the order, GRINTECH will do so.

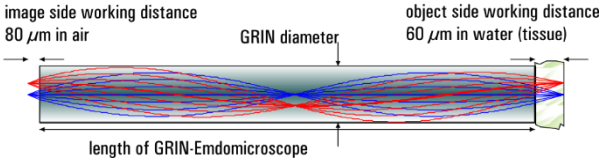
www.inscopix.com

For more information, please contact info@grintech.de

GRIN Needle Endomicroscopes for Fluorescence Microscopy

GRIN Needle Endomicroscopes are used for deep tissue imaging. They relay the micron-scale resolved image of the tissue over a longer length to a plane outside of the tissue at the other end of the needlescope. They are used with epi - fluorescence imaging (Design Wavelength 520 nm). The Endomicroscopes are fabricated as GRIN-singlets with NA = 0.50 on both sides or as GRIN-doublets with an object NA of 0.5 and an image NA of 0.19. Working distances on object side are specified in water or tissue, on image side in air. They are offered in different lengths resulting from adding 0.5 GRIN-pitches (periods) to the GRIN. Optional, they can be offered as side viewing needlescope by adding a 90° prism on object side.

Singlets:

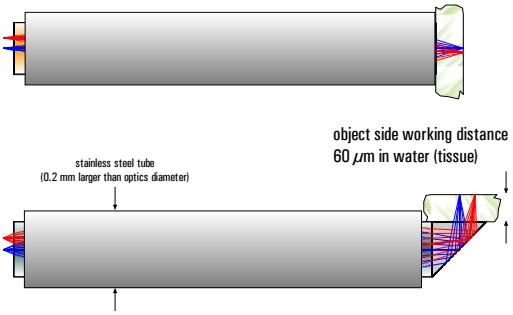


- object side working distance in water: 60 µm
- image side working distance in air: 0 µm / 80 µm
- design wavelength: 520 nm
- NA Object / image side: 0.50 / 0.50
- Magnification: 1:1 / 1:-1 (depending on pitch length)

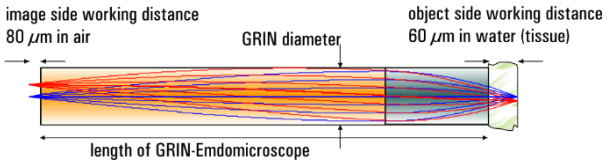
Available lengths:

Diameter (mm)	Product Code	Image side working distance (µm)	Length (mm)
0.50	NEM-050-06-00-520-S-0.5p	0	2.22
	NEM-050-06-08-520-S-0.5p	80	2.08
	NEM-050-06-08-520-S-1.0p	80	4.38
	NEM-050-06-08-520-S-1.5p	80	6.67
	NEM-050-06-08-520-S-2.0p	80	8.96
1.00	NEM-100-06-00-520-S-0.5p	0	4.67
	NEM-100-06-08-520-S-0.5p	80	4.54
	NEM-100-06-08-520-S-1.0p	80	9.28
	NEM-100-06-08-520-S-1.5p	80	14.02

- Other diameters (0.35 mm, 0.60 mm, 0.85 mm, 1.80 mm or 2.00 mm), other working distances or other design wavelength are available on request



Doublets:



- object side working distance in water: 60 µm
- image side working distance in air: 80 µm
- design wavelength: 520 nm
- NA Object / image side: 0.50 / 0.19
- Magnification: 1:2.6 / 1:-2.6 (depending on pitch length

Available lengths:

Diameter (mm)	Product Code	Length (mm)
0.50	NEM-050-06-08-520-DS	3.98
	NEM-050-06-08-520-DM	10.08
	NEM-050-06-08-520-DL	16.19
1.00	NEM-100-06-08-520-DS	8.28
	NEM-100-06-08-520-DM	20.50

- Other diameters (0.35 mm, 1.8 mm), other working distances or other design wavelength are available on request

Notes:

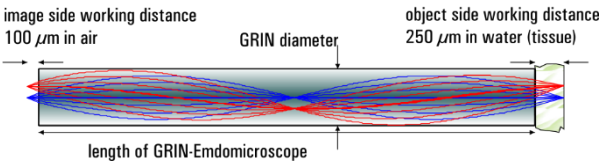
- Diameters are sole GRIN-optics diameters
- Optional the Endomicroscopes can be delivered in medical-grade stainless steel tubes (1.4301), with outer diameters of 0.70 mm for 0.5 mm optics and 1.2 mm for 1.0 mm optics. The tubes are mounted flush on the object side (tissue, high NA) for the side viewing version the prism is not protected by the tube..
  On the image side, the optics sticks out of the tube by 50 – 500 µm.
  Please add –ST to the product code if desired.
- The lengths can have a tolerance of +/- 5 %.
- The lenses are non-coated. For customized projects, the lenses can be AR-coated.
- A side-viewing scope using microprisms may be also possible on a customized basis (see left).
- Please ask for combination with imaging fiber bundles (Fujikura) as customized solution.
- For tolerances, handling and storage see page 26

* Please note our partnership with Inscopix as our exclusive distributor for neuroscience applications in non-humans (see page 8).

GRIN Needle Endomicroscopes for 2-Photon Microscopy

GRIN Needle Endomicroscopes are used for deep tissue imaging. They relay the micron-scale resolved image of the tissue over a longer length to a plane outside of the tissue at the other end of the needlescope. They are used with multi-photon fluorescence imaging (Design Wavelength 860 nm). The Endomicroscopes are fabricated as GRIN-singlets with NA = 0.50 on both sides or as GRIN-doublets with an object NA of 0.5 and an image NA of 0.19. Working distances on object side are specified in water or tissue, on image side in air. They are offered in different lengths resulting from adding 0.5 GRIN-pitches (periods) to the GRIN. Optional, they can be offered as side viewing needlescope by adding a 90° prism on object side.

Singlets:

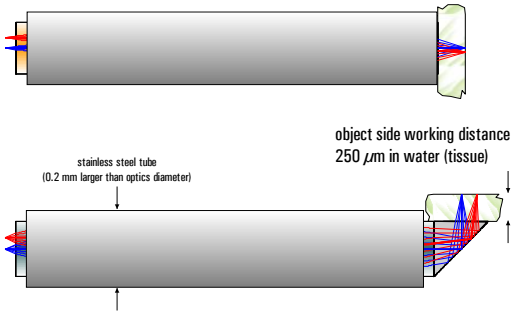


- object side working distance in water: 250 µm
- image side working distance in air: 100 µm
- design wavelength: 860 nm
- NA object / image side: 0.50 / 0.50
- Magnification: 1:1 / 1:-1 (depending on pitch length)

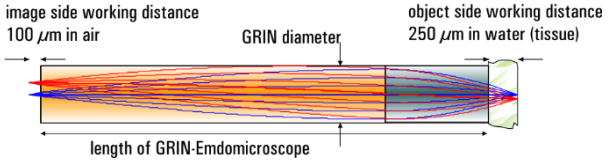
Available lengths:

Diameter (mm)	Product Code	Length (mm)
0.50	NEM-050-25-10-860-S-0.5p	1.87
	NEM-050-25-10-860-S-1.0p	4.20
	NEM-050-25-10-860-S-1.5p	6.52
	NEM-050-25-10-860-S-2.0p	8.85
1.00	NEM-100-25-10-860-S-0.5p	4.38
	NEM-100-25-10-860-S-1.0p	9.22
	NEM-100-25-10-860-S-1.5p	14.07

- Other diameters (0.35 mm, 0.60 mm, 0.85 mm, 1.80 mm or 2.00 mm), other working distances or other design wavelength are available on request



Doublets:



- object side working distance in water: 250 µm
- image side working distance in air: 100 µm
- design wavelength: 860 nm
- NA object / image side: 0.50 / 0.19
- Magnification: 1:2.6 / 1:-2.6 (depending on pitch length)

Available lengths:

Diameter (mm)	Product Code	Length (mm)
0.50	NEM-050-25-10-860-DS	3.79
	NEM-050-25-10-860-DM	9.89
	NEM-050-25-10-860-DL	16.00
1.00	NEM-100-25-10-860-DS	8.09
	NEM-100-25-10-860-DM	20.09

- Other diameters (0.35 mm, 1.80 mm), other working distances or other design wavelength are available on request

Notes:

- Diameters are sole GRIN-optics diameters
- Optional the Endomicroscopes can be delivered in medical-grade stainless steel tubes (1.4301), with outer diameters of 0.70 mm for 0.5 mm optics and 1.2 mm for 1.0 mm optics. The tubes are mounted flush on the object side (tissue, high NA) for the side viewing version the prism is not protected by the tube..
  On the image side, the optics sticks out of the tube by 50 – 500 µm.
  Please add –ST to the product code if desired.
- The lengths can have a tolerance of +/- 5 %.
- The lenses are non-coated. For customized projects, the lenses can be AR-coated.
- A side-viewing scope using microprisms may be also possible on a customized basis (see left).
- Please ask for combination with imaging fiber bundles (Fujikura) as customized solution.
- For tolerances, handling and storage see page 26

* Please note our partnership with Inscopix as our exclusive distributor for neuroscience applications in non-humans (see page 8).

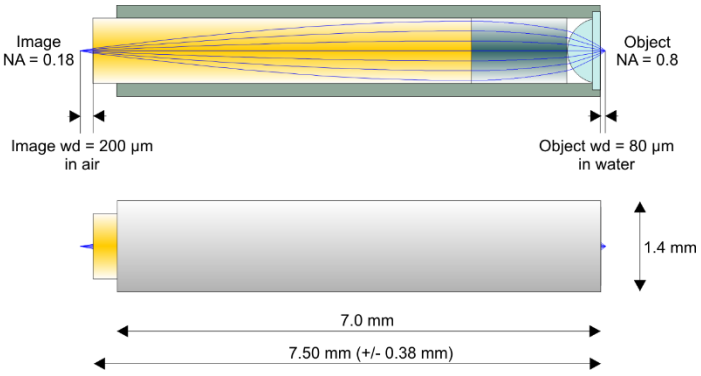
High-NA Endomicroscopic Imaging Objective for Fluorescence Microscopy

GRINTECH's high-NA Endomicroscopic Imaging Objectives cascade the optical power of a plano-convex lens and a GRIN lens with aberration compensation to achieve an object NA of 0.8.

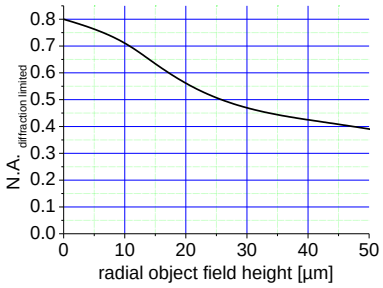
Applications: In vivo endomicroscopy, fluorescence microscopy, tissue imaging, flexible fluorescence microscopy, NA conversion

Product Code: GT-MO-080-018-488

Features:
- Object NA = 0.80
- Object working distance 80 µm (water)
- Image NA = 0.18
- Magnification 4.65 x
- Recommended Excitation 488 nm
- Mounted in stainless steel holder

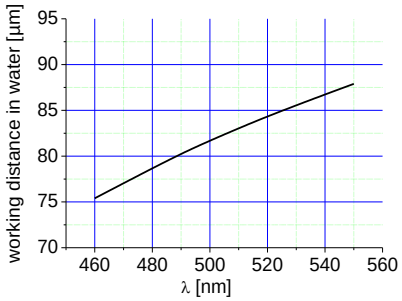


Diffraction limited NA versus Field



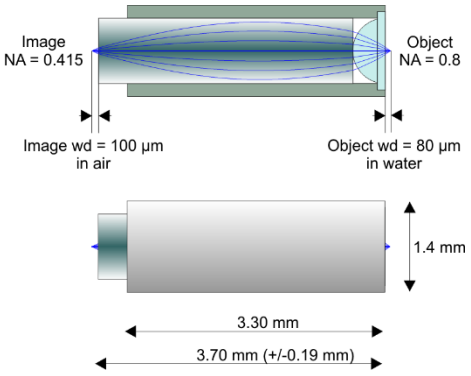
(from optical design simulation according to Marechal criterion @ 488 nm, wavefront RMS ≤ 0.07 λ)

Chromatic Aberration in Object Space

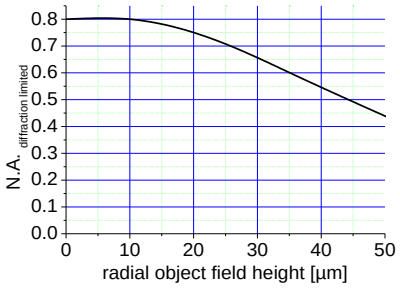


Product Code: GT-MO-080-0415-488

Features:
- Object NA = 0.80
- Object working distance 80 µm (water)
- Image NA = 0.415
- Magnification 1.92 x
- Recommended Excitation 488 nm
- Mounted in stainless steel holder

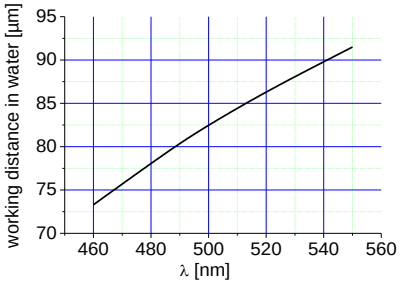


Diffraction limited NA versus Field



(from optical design simulation according to Marechal criterion @ 488 nm, wavefront RMS ≤ 0.07 λ)

Chromatic Aberration in Object Space



Variations due to modifications of the production process are possible. It is the user´s responsibility to determine suitability for the user´s purpose.
For tolerances, handling and storage see page 26
Pat. US 7,511,891

High-NA Endomicroscopic Imaging Objective for 2-Photon Microscopy

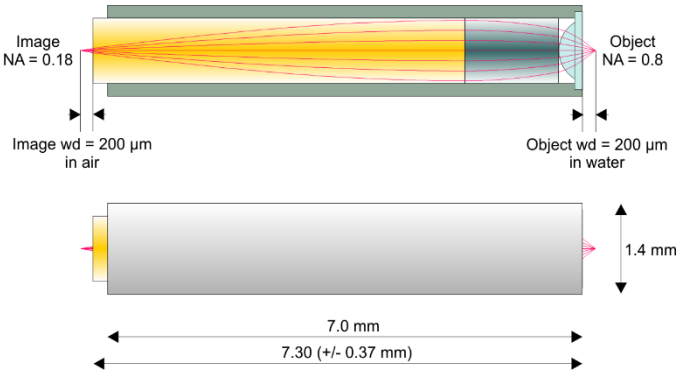
GRINTECH's high-NA Endomicroscopic Imaging Objectives cascade the optical power of a plano-convex lens and a GRIN lens with aberration compensation to achieve an object NA of 0.8.

Applications: In vivo endomicroscopy, 2-photon microscopy, deep brain and tissue imaging, flexible fluorescence microscopy, NA conversion

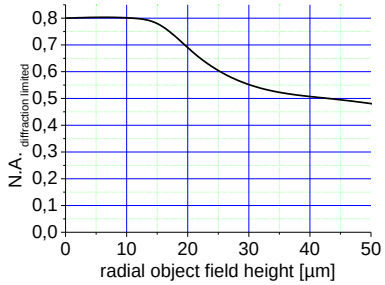
Product Code: GT-MO-080-018-810

Features:

- Object NA = 0.80
- Object working distance 200 μm (water)
- Image NA = 0.18
- Magnification 4.8 x
- Recommended Excitation 800 – 900 nm
- Mounted in stainless steel holder

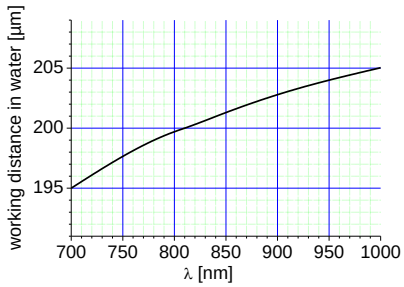


Diffraction limited NA versus Field



(from optical design simulation according to Marechal criterion @ 810 nm, wavefront RMS ≤ 0.07 λ)

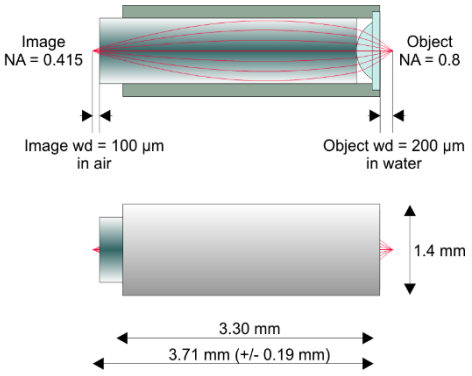
Chromatic Aberration in Object Space



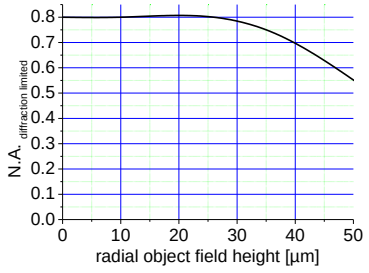
Product Code: GT-MO-080-0415-810

Features:

- Object NA = 0.80
- Object working distance 200 μm (water)
- Image NA = 0.415
- Magnification 1.92 x
- Recommended Excitation 800 – 900 nm
- Mounted in stainless steel holder

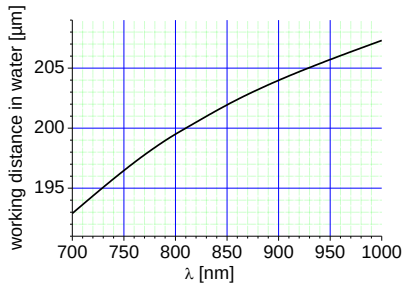


Diffraction limited NA versus Field



(from optical design simulation according to Marechal criterion @ 810 nm, wavefront RMS ≤ 0.07 λ)

Chromatic Aberration in Object Space



Variations due to modifications of the production process are possible. It is the user´s responsibility to determine suitability for the user´s purpose.
For tolerances, handling and storage see page 26
Pat. US 7,511,891

High-NA chromatic and field corrected Endomicroscopic Imaging Objectives (MO-ACR)

GRINTECH's high-NA Endomicroscopic Imaging Objectives with object Numerical Apertures of 0.75 are offered in a broad achromatic and field corrected version to significantly increase the usable field of view. A GRIN-refractive multilens hybrid design allows a broader chromatic and off-axis correction resulting also in a higher confocal sensitivity (confocal signal throughput) compared to the previous versions with diffractive correcting elements.

Applications:

In vivo endomicroscopy, single photon fluorescence microscopy, nonlinear optical imaging modalities (SHG, TPF), tissue imaging, flexible fluorescence microscopy, NA conversion

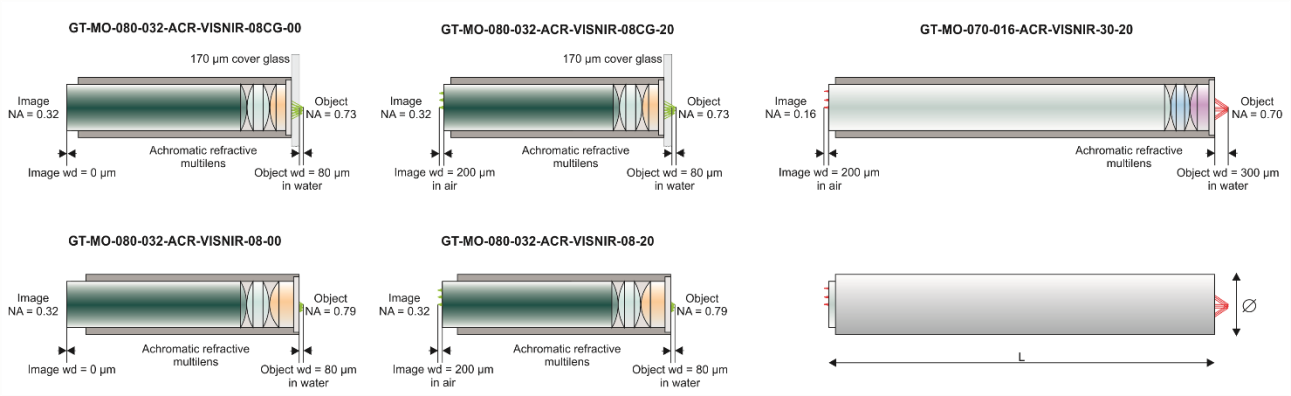
GT-MO-080-032-ACR-VISNIR-xx-xx series represents high resolution field and color corrected objectives with a magnification of 2.3. The image side NA of 0.32 matches to imaging fiber bundles. Color correction is from 450 nm to 900 nm with an optimal performance from 488 nm to 520 nm. The objectives are assembled in stainless steel mounts.

GT-MO-070-016-ACR-VISNIR-30-20 is optimized for wavelengths of 450 nm and 900 nm to achieve an ideal performance in SHG and TPF applications within a large field of view.

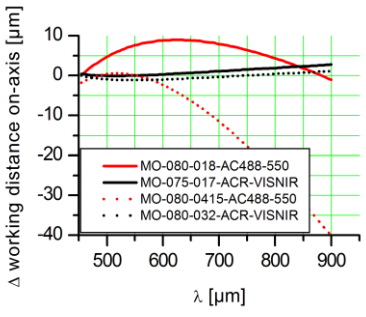
Four combinations of proximal and distal working distances are offered as listed below:

GT-MO-080-032-ACR-VISNIR-...	...08CG-00	...08CG-20	...08-00	...08-20
Object NA	0.73	0.73	0.79	0.79
Object WD in water [μm]	80	80	80	80
Designed for cover glass [μm]	170	170	none	none
Image NA	0.32	0.32	0.32	0.32
Image WD in air [μm]	0	200	0	200
Magnification	2.2	2.2	2.3	2.3
Dimensions Ø / L [mm]	1.3 / 4.89	1.3 / 4.57	1.3 / 5.02	1.3 / 4.7

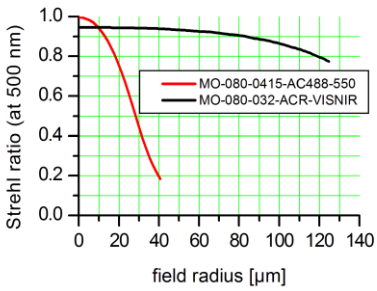
GT-MO-070-016-ACR-VISNIR-30-20
0.7
300
none
0.16
200
4.5
1.3 / 8.36

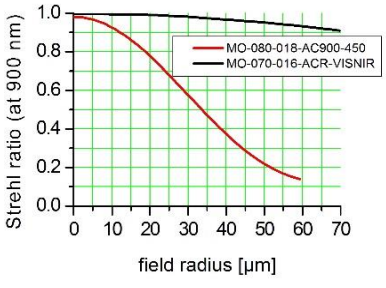


Chromatic Aberration in Object Space



Field Dependent Strehl Ratio in Object Space (From Optical Design)





Variations due to modifications of the production process are possible. It is the user´s responsibility to determine suitability for the user´s purpose.
For tolerances, handling and storage see page 26

Application Note – High NA chromatic and field corrected Endomicroscopic Imaging Objectives

The generation of GRINTECH's color and field corrected high-NA **MO-ACR** objectives resolve cellular details in micron resolution from center to the margin of the aperture

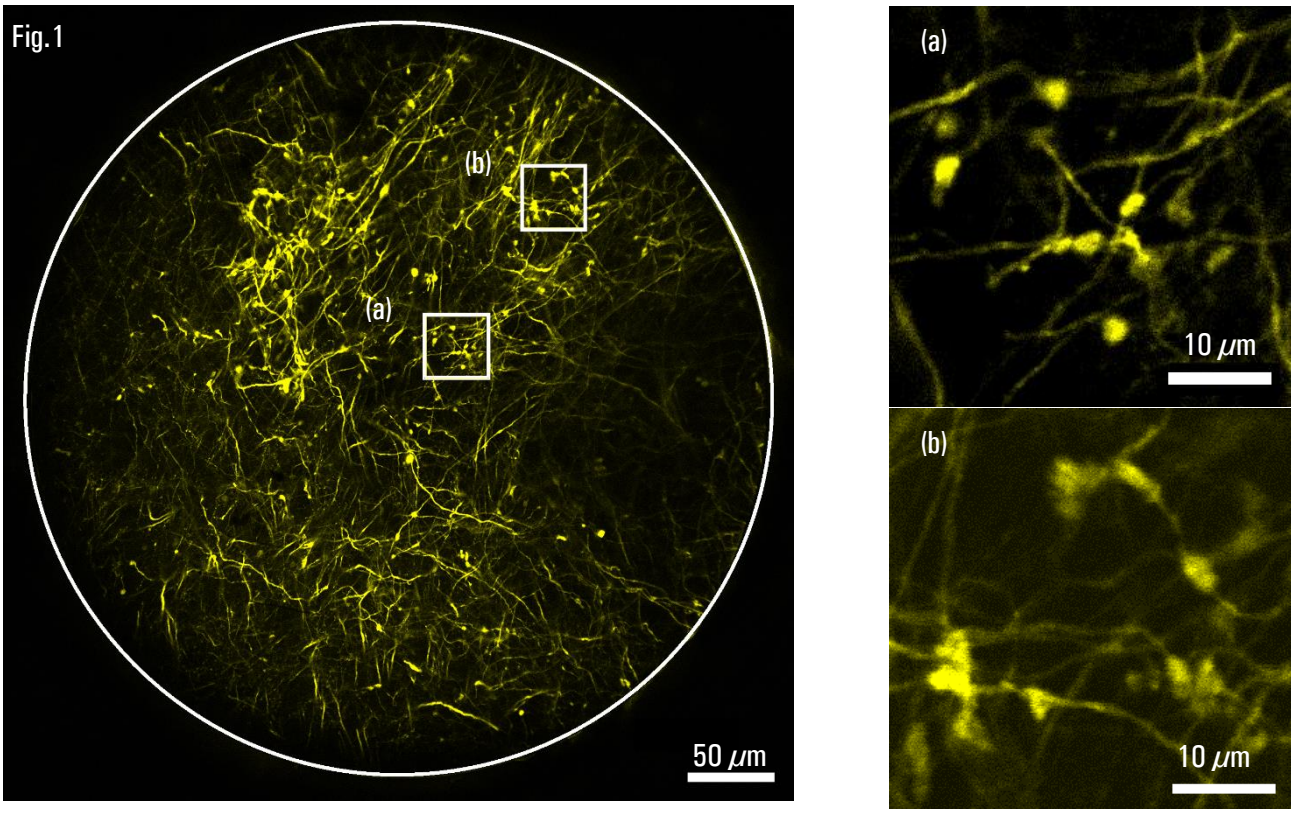


Fig.1: Mouse brain section, PFA fixation, cover glass 170 µm confocally imaged in fluorescence (exc. 488nm) with **GT-MO-080-032-ACR-VISNIR-08CG-00** coupled to Olympus FV1000 with MO 10x; NA=0.4 with XYZ-Stage. White circle shows backside aperture of 1 mm corresponding to full object FOV of 450 µm, with optimal imaging quality in FOV of 360 µm. **(a)** and **(b)**: 40 µm x 40 µm sections of the center and edge of object FOV.

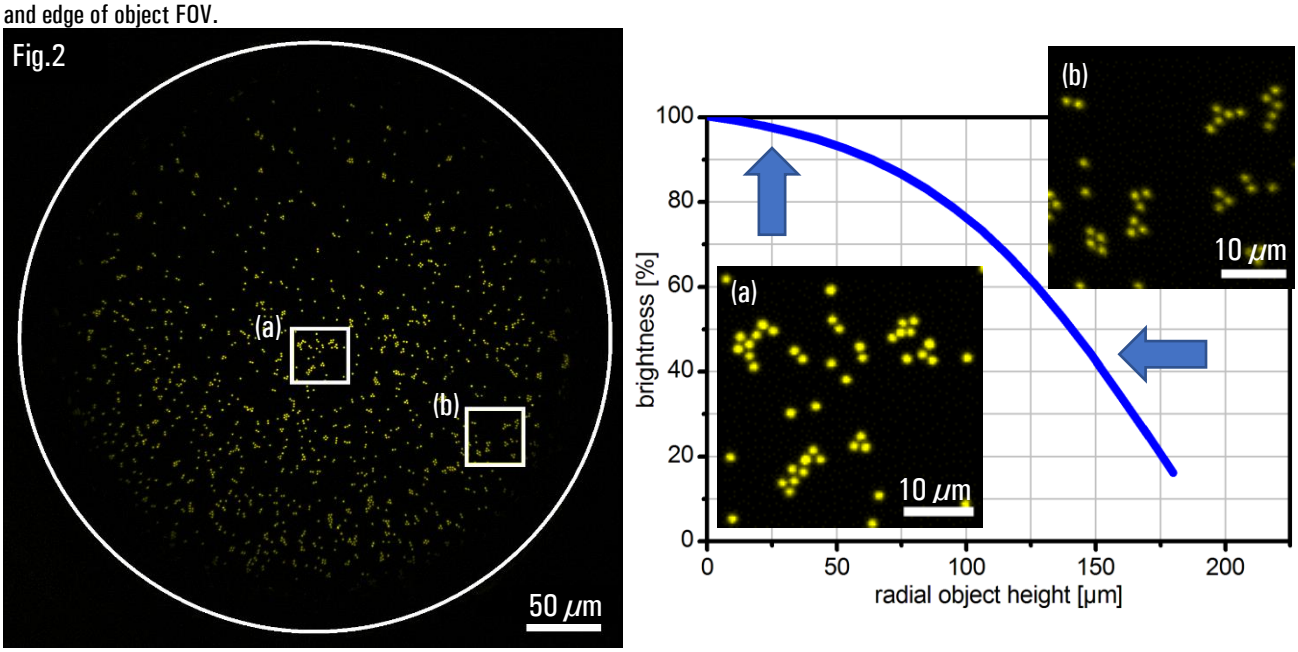


Fig.2: fluorescence beads with Ø=2µm yellow/green acquired with **GT-MO-080-032-ACR-VISNIR-08-00**. Right: bead brightness depending on the radial object height. (a) and (b) 40 µm x 40 µm sections from the center and edge of object FOV.

The usable field of view is increased to 300 % in diameter compared to previous MO-080 objectives

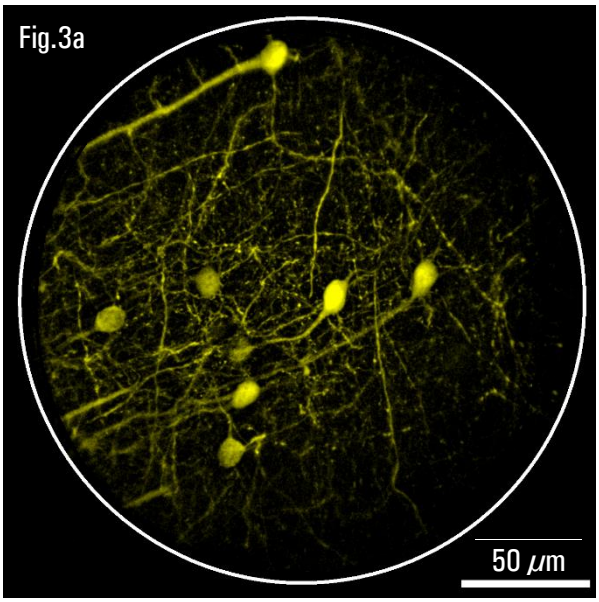


Fig.3a: GT-MO-070-016-ACR-VISNIR-30-20 with full object FOV of 200 µm (optimal imaging in 150 µm) compared to **Fig.3b.**

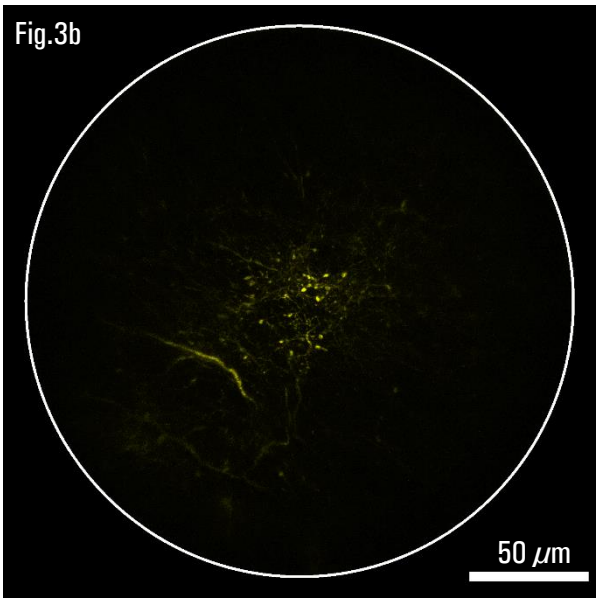


Fig.3b: GT-MO-080-018-AC900-450 with FOV of 65 µm

Now available also in 1.3 mm outer diameter instead of 1.4 mm

For more details, please contact GRINTECH.

High-NA chromatically and field corrected Endomicroscope Tube for CARS and non-linear imaging

GRINTECH's high-NA Endomicroscope tube with object Numerical Aperture of 0.50 features sub-micron resolution imaging with a field of view of 300 μm for CARS/2-Photon-Fluorescence/SHG modalities. It has a diameter of 3.0 or 2.2 mm and a rigid length of 178 mm. A GRIN-refractive multilens hybrid design allows chromatic and off-axis correction between 795 nm and 1029 nm.

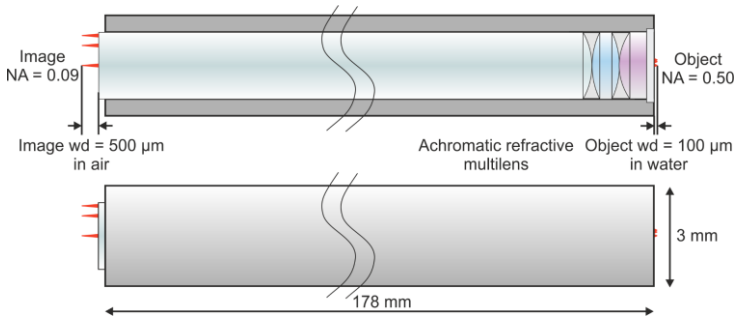
Applications:

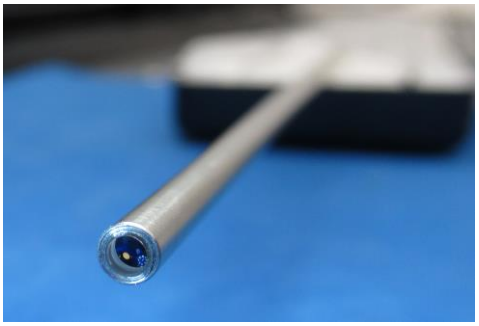
In vivo endomicroscopy, nonlinear optical endoscopy (CARS, SHG, TPF), tissue imaging, proximal scanning, NA conversion

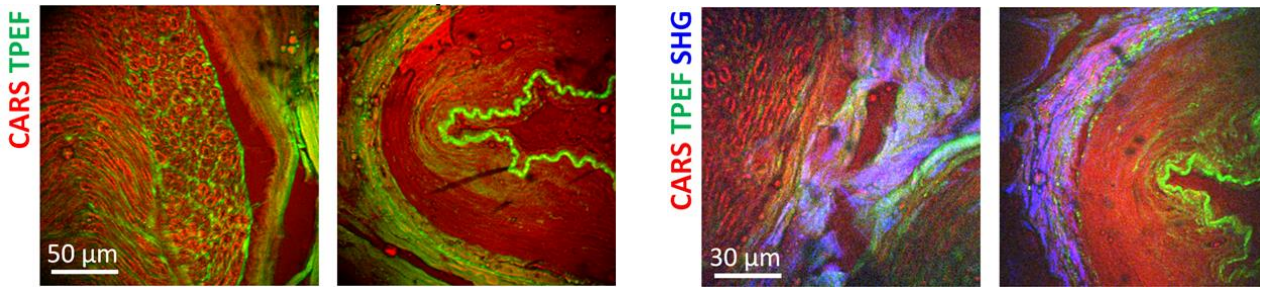
GT-MO-050-009-ACR795/1029-10-50 represents a high resolution field- and NIR-chromatically corrected objective with a magnification of 5.6. The image side NA of 0.09 matches to low NA telecentric spot scanning. Chromatic correction is realized between 795 nm to 1029 nm together with an optimal performance.
The optics is assembled in a stainless steel tube of 3.0 or 2.2 mm diameter (optional).

Specifications:

GT-MO-050-009-ACR795/1029-10-50	
Object NA	0.50
Object WD in water [μm]	100
Image NA	0.09
Image WD in air [μm]	Approx. 500
Magnification	5.6
Dimensions Ø / L [mm]	3.0 or 2.2 / 178







Images:

Human nervus suralis – cryosection, images recorded through Endomicroscopic tube + Plan-Apo 5x/0.16 + Zeiss CARS LSM (Courtesy by TU Dresden)

Reference: Zirak, P., et al. (2018). "Invited Article: A rigid coherent anti-Stokes Raman scattering endoscope with high resolution and a large field of view." APL Photonics **3**(9): 092409.

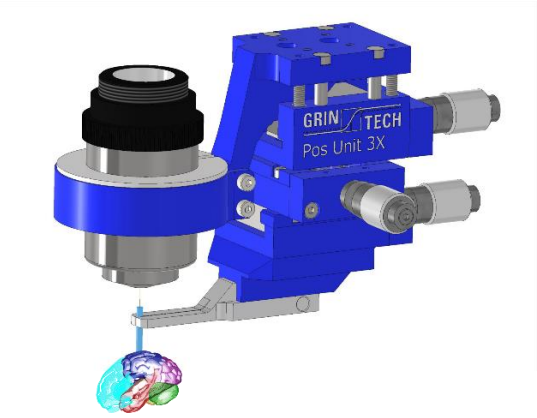
Variations due to modifications of the production process are possible. It is the user´s responsibility to determine suitability for the user´s purpose.
For tolerances, handling and storage see page 26

PosUnit 3x for GRIN-Needle Endomicroscopes and High NA Objectives

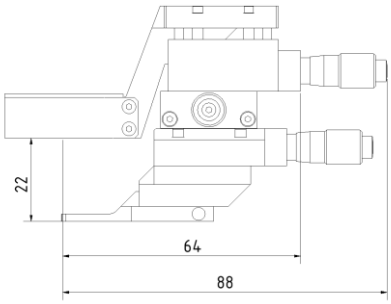
XYZ Stage and objective mounting to connect and align to microscope objectives

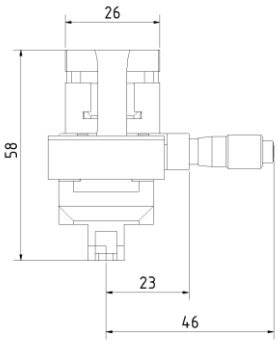
PosUnit 3X

Applications and properties



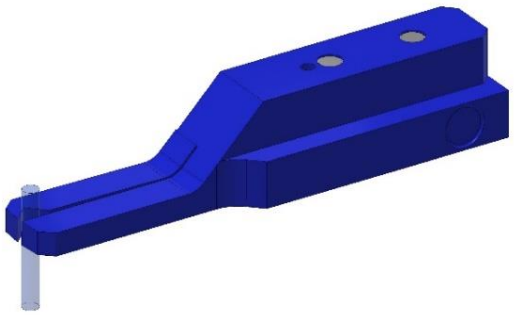
- holding, handling and three-axis-positioning of GRIN-microsystem relative to microscope objectives
- mounting for microscope objective diameter 35mm (standard)
- smaller microscope objective diameters are possible with assistance of an adapter ring
- stable and reliable construction of the XYZ-stage
- adjustment travel: X - 5 mm, Y - 5 mm, Z - 5 mm with scale reading in all axis, bar distance 10 μm.
- easy pick and drop of GRIN Lenses with a resiliently mounted snap system
- Jaw seat fits exactly to the jaws of the previous model
- durable anodized aluminum surface
- clamping unit not included



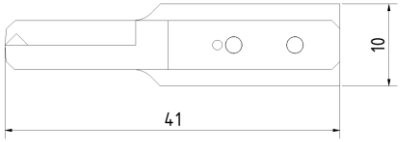


Clamping unit

Applications and properties

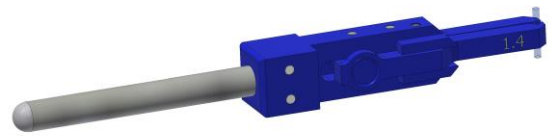


- Holding device for grin lenses to be accommodated within the Pos Unit 3X
- different prism groove sizes available for diameter: **0.5** / **0.7** / **1.0** / **1.2** / **1.4** mm
- resiliently mounted snap system for easy pick and drop andhandle of GRIN Lenses, now guided by precise axis
- magnetic holder for PosUnit 3X
- durable anodized aluminum surface



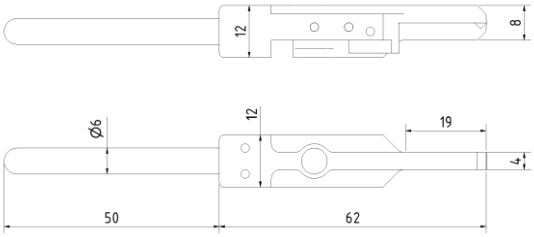
GRIN Lens Gripper for GRIN-Lenses, Needle Endomicroscopes and High NA Objectives

GRIN Lens Gripper

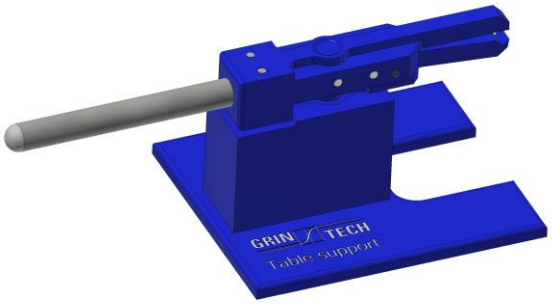


Applications and properties

- Basic Unit - GRIN Lens Gripper
- Holding device for grin lenses
- different prism groove sizes available for diameter: **0.5** / **0.7** / **1.0** / **1.2** / **1.4** mm
- springy-loaded snap system for easy pick up and handle micro-optics
- durable anodized aluminum surface

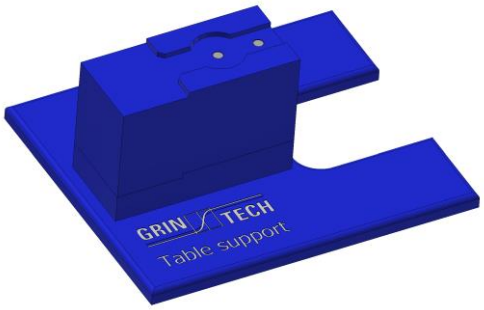


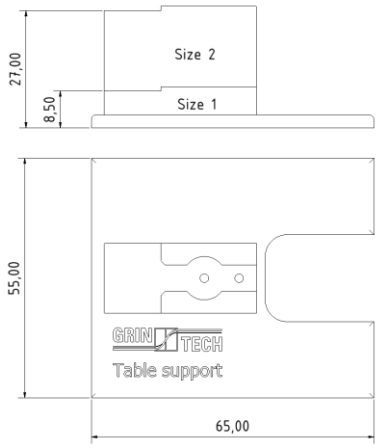
Tool - Table support



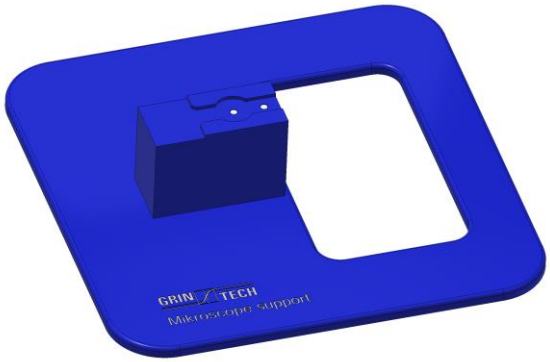
Applications and properties

- Table support for GRIN Lens Gripper
- for cleaning and inspection on table
- horizontal and vertical storage of the lens axis possible
- Shelf heights available in 8.5mm and 27mm from the table surface
- magnetic holder
- durable anodized aluminum surface



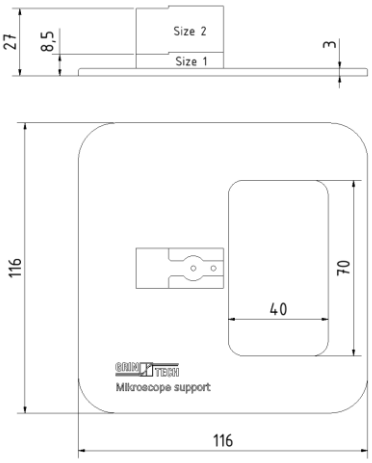


Tool - Microscope support

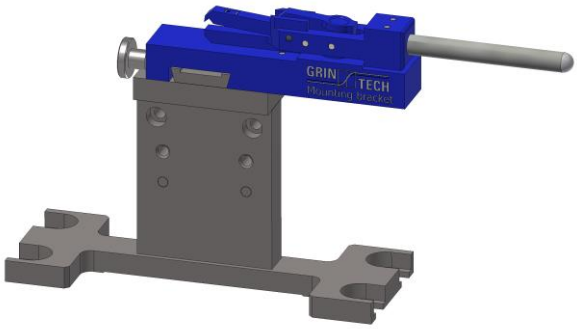


Applications and properties

- Microscope support for GRIN Lens Gripper
- for cleaning and inspection on Microscope
- horizontal and vertical storage of the lens axis possible
- Shelf heights available in 8.5mm and 27mm from the Support surface
- magnetic holder
- durable anodized aluminum surface

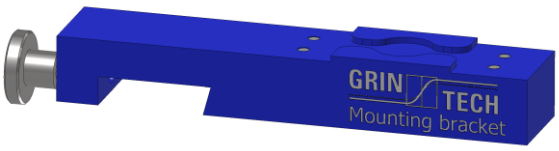


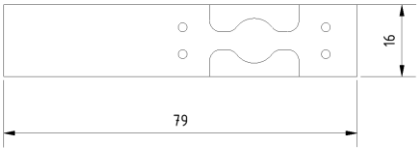
Tool Mounting Bracket



Applications and properties

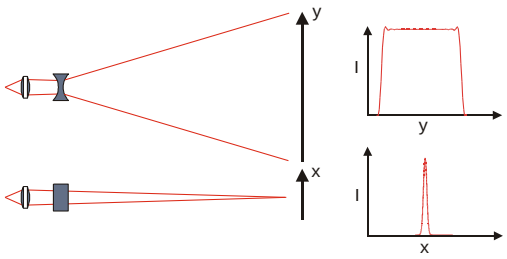
- for mounting GRIN Lens Gripper on Newport ULTRAalign™ system
- measuring and inspection on Newport ULTRAalign™ system
- magnetic holder
- durable anodized aluminum surface





Small Size Laser-Optic Line Generator

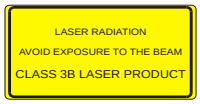
GRINTECH's Gradient-Index Micro-Optic Components with plane optical surfaces generate a homogeneous laser line from a Gaussian beam of a single-mode laser diode. The extraordinary small module size of ∅ 6.43 mm x 10.5 mm and a weight of only 1.5 g are combined with a line uniformity of approx. ± 8% and a diffraction-limited focus size.



Applications: 3D contour mapping
Optical alignment
Machine vision
Biomedical

Standard Options:

- Line divergence (Fan angle): ± 10°, ± 15°, ± 20° (see ordering information below)
- Line focus position can be specified between 80 mm and infinity (collimation) when ordering. Please see remarks below for focus size and depth of focus.
- Red laser diode: QDLaser – QLF063A-AA, λ = 660 nm, P_{LD} = 50 mW, TO-18 (∅ 5.6 mm) package (driver on request)
- Input laser beam specification for laser diodes TO-18:
  Slow axis divergence: 9 deg. (+ 1.5 / - 0.5 deg.) @ FWHM



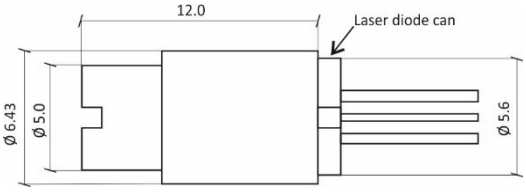
Mechanical Specifications:

- Weight: 1.5 g
- Dimensions version 1: ∅ 6.43 mm x 12.0 mm
- Dimensions version 2: ∅ 8.00 mm x 12.0 mm
- Package material: anodised aluminium

Environmental Specifications:

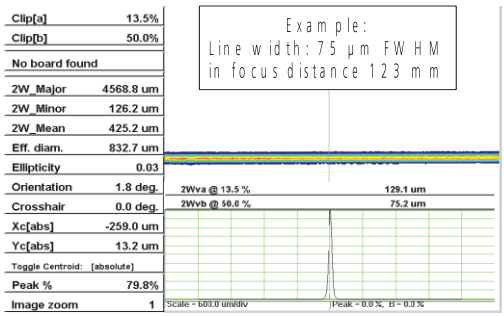
- Operating temperature: 0 ... 50°C
- Storage temperature: -20°C ... +70°C
- Resistance to vibrations: 2 g / 20 ... 500 Hz (acc. IEC68-2-6)
- Resistance to mechanical shock: 15 g / 6 ms (acc. IEC68-2-29)
- Laser safety class: depending on application and additional optics up to class 3B

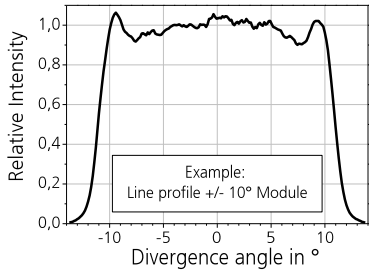
Dimensions Version 1:



Optical Specifications:

- Fan divergence angles : ± 10°, ± 15°, ± 20°
- Focus distance: 80 mm – infinity, Gaussian shape
- Line width in focus: FWHM/Distance = 0.60 µm/mm,
  Example: approx. 120 µm line width (FWHM) in 200 mm distance
- Far field divergence depending on line widths, approx. according to Gaussian beam laws
- Squint angle: ≤ 2°
- Transmission efficiency: P_{out} / P_{LD} = 90 – 95%





Variations due to modifications of the production process are possible. It is the user´s responsibility to determine suitability for the user´s purpose.

Order example:

GT – LLGM – 643 – DA – FD	
GT	GRINTECH
LLGM	Laser Line Generator Modul
643	Diameter: 6.43 mm
DA	Divergence Angle: 10 for ±10° 15 for ±15° 20 for ±20°
FD	Focus distance in mm (between 80mm and infinity)

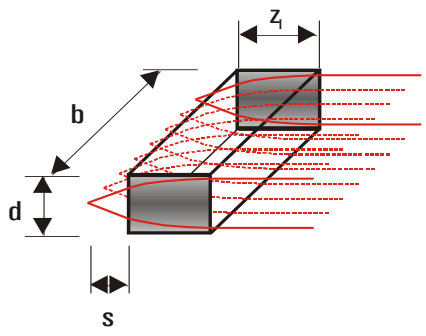
Customization - GRIN Cylindrical Lenses

Applications:

- Fast Axis Collimation of High Power Laser Diode Bars
- High Brightness Diodes
- Beam Shaping Purposes

In addition to our standard products, GRINTECH offers GRIN cylindrical lenses according to customer specifications.
Please ask us and let us know your requirements as detailed as possible (the closer we know your specifications the better we can advise you).

Working Distance (s):
Design wavelength:
Lens length (z_l):
Width (b):
Coating:
Quantity:



Customization - GRIN Fiber Assemblies

Applications:

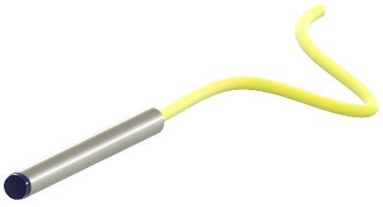
- Focussing Probes
- Collimators
- Fiber Coupling
- Fiber optical sensors

In addition to our standard products, GRINTECH offers fiber optic probes and assemblies according to customer specifications. Please ask us and let us know your requirements as detailed as possible (the closer we know your specifications the better we can advise you).

For the optical and mechanical design and the quotation we need at least the following information:

Fiber type: for example: single mode, polarization maintaining, multimode, or special fiber please specify operating wavelength (for SM, PM), core size (for MM)
Fiber length:
Connector: FC/PC, FC/APC or other (please specify)
Design wavelength:
Diameter of the optical components: 0.5, 1.0 or 1.8 mm
Housing of the optical part: none or stainless steel tube (please specify outer diameter and length of tubing)
Focusing probe: please specify working distance / Spot size (diameter @1/e²)
Collimating probe: please specify beam diameter (@1/e²)
Others: For example: prism for side firing, 8° angled facet for reducing back reflections, AR coating, ...
Quantity:

Typical configurations:



GRIN-Lens Ø 1.80 mm
Stainless Steel Tube Ø 2.00 mm
Fiber

GRIN-Lens Ø 1.00 mm / Prism 1.00 mm
Stainless Steel Tube Ø 1.20 mm
Fiber

GRIN-Lens Ø 1.00 mm / Prism 1.00 mm
Stainless Steel Tube Front Ø 1.20 mm
Stainless Steel Tube Back
Fiber

Customization - GRIN Biophotonic Probes – Imaging Probes

Applications:

- Imaging Probes

In addition to our standard products, GRINTECH offers imaging fiber bundle assemblies with imaging micro - optics according to customer specifications.
Please ask us and let us know your requirements as detailed as possible (the closer we know your specifications the better we can advise you).

For the optical and mechanical design and the quotation we need at least the following information:

For Imaging Probes

Fiber bundle type (Fujikura): FIGH-10-350S, FIGH-10-500N, FIGH-30-850N, **other**
Fiber bundle Length:
Connector: none or FC/PC
Working distance:
Diameter of the optical components: 0.5 or 1.0 mm
Others: For example: prism for side firing, ...
Quantity:

Typical configurations:

GRIN-Lens
Stainless Steel Tube
Imaging Fiber Bundle

GRIN-Lens
Prism
Stainless Steel Tube
Imaging Fiber Bundle

Customization - GRIN Biophotonic Probes – OCT/Focussing Probes

Applications:

- OCT / Focussing Probes

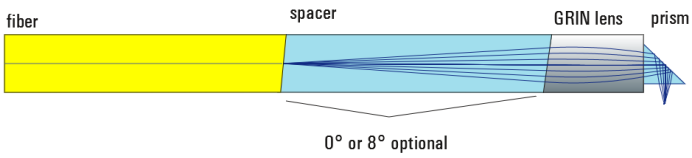
In addition to our standard products, GRINTECH offers fiber optic assemblies according to customer specifications.
Please ask us and let us know your requirements as detailed as possible (the closer we know your specifications the better we can advise you).

For the optical and mechanical design and the quotation we need at least the following information:

For OCT / Focussing Probes

Fiber type: single mode, polarization maintaining, or special fiber please specify operating wavelength (for SM, PM)
Fiber length:
Connector: FC/PC, FC/APC or other (please specify)
Design wavelength:
Diameter of the optical components: 0.5, 1.0 or 1.8 mm
Working distance / Spot size: For spot size please specify diameter @1/e²
Housing of the optical part: none or stainless steel tube (please specify outer diameter and length of tubing)
Others: For example: prism for side firing, 8° angled facet for reducing back reflections, AR coating, ...
Quantity:

Typical configuration:



Development of Customized GRIN Systems

In addition to our standard products and customized systems, GRINTECH offers more sophisticated solutions as customized developments.

Please ask us and let us know your requirements as detailed as possible. The closer we know your specifications the better we can advise you.

Our development services include

- Zemax design studies
- Adaption of the refractive index profile (NA, higher order correction)
- Coatings (special AR coatings, beam splitting coatings, reflectivity coatings, ...)
- Stops (aperture and field stops)
- Chromatic corrections
- ...

The following examples show some customer inspired systems and may illustrate the possibilities.

Example configurations:

lens diameter: 1.0 mm / 2.0 mm,
with beam splitting cube

lens diameter: 2.0 mm,
with beam splitting cube and prism

Tolerances / Handling Instructions

Tolerances:

For of our single lenses we have the following fabrication tolerances and quality criteria:

Tolerances:		Surface quality:
lens length z:	± 5% due to variations of the gradient constant	5 / 3 x 0.025; L 3 x 0.005; E 0
working distance s:	± 0.02 mm (only LFRL- and CFRL lens series)	(defined by DIN ISO 10110-7:2000-02).
diameter d:	+ 0 / -0.01 mm	The surface quality is defined within 90 % of the lens diameter.
	- tighter diameter tolerances on request	Outside of this area defects are allowed.

Storage and Handling of Lenses

Storage

GRIN lenses and lens systems should be stored in a dry environment. For short term storage, the plastic box or foam packing in which the lenses are shipped will provide adequate storage.

Recommended storage temperature: -20°C - 80°C.

Storage boxes should ensure that the lenses do not touch each other to prevent chipping and scratches. Best is to use the original box.

Handling

Lenses should be carefully handled with plastic tweezers, preferably those with a tapered end. Lenses should be picked up out of their individual compartments by firmly holding each on its side cylinder surface (not the polished ends). Especially small sized lenses may stick to the lens box material and can be lost during removal.

Cleaning

If it is necessary to clean the lens surfaces due some dust or other contaminant which may impair the optical performance.
GRINTECH generally recommends the use of ethyl alcohol as a cleaning solvent, maybe combined with some smooth lintfree lens cleaning tissue.
Acetone may also be used, but it should be pure enough, otherwise it might leave some residue on the lens surface.

Gradient Index (GRIN) Lenses

- GRIN rod lenses for fiber coupling
- GRIN cylindrical lenses for beam shaping of high power laser diode bars and high brightness diodes
- easy to assemble due to the plane surfaces
- good off- and on-axis performance
- non-toxic silver and lithium ion exchange

Gradient Index Optics

GRIN lenses represent an interesting alternative to conventional spherical lenses since the lens performance depends on a continuous change of the refractive index within the lens material. Instead of curved shaped surfaces only plane optical surfaces are used. The light rays are continuously bent within the lens until finally they are focussed on a spot.

Fig. 1 GRIN lens Conventional spherical lens

The GRIN lenses are produced by silver ion exchange in a special glass. The composition of the glass is protected by a patent. In contrast to the conventionally used technology this is a non-toxic process and bears no health and environmental risks for both the producer as well as the user of these products. This process is performed in rods and slabs resulting in rod lenses and cylindrical lenses with plane optical surfaces.
A radial refractive index profile of nearly parabolic shape

$$n(r) = n_0 \,\mathrm{sech}(gr)$$

realizes a continuos cosine ray trace within a GRIN focussing lens, the period length $z_{1\text{-}p}$ of the lens is given by

$$z_{1-p} = \frac{2\pi}{g}$$

and does not depend on the entrance height and the entrance angle of the light ray (see Fig 2). n_0 represents the refractive index at the center of the profile, r the radius and g the gradient constant.

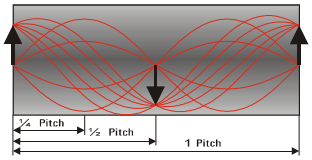


Fig. 2. Ray traces within a GRIN focussing lens of different pitch lengths

The geometrical length of the particular lens z_l is calculated from the characteristic pitch of the lens P,

$$z_l = \frac{2\pi}{g} P$$

Various imaging designs can be realized using the same index profile by choosing different lens lengths:
A 1- (2, 3, or more, respectively)-pitch lens reproduces an object placed in the entrance surface of the lens identically into the exit surface.

A half-pitch lens images an object on the entrance surface inverted to the exit surface of the lens.
A quarter-pitch lens images a point source on the entrance surface of the lens into infinity or collimates it, respectively. This configuration is usually applied to the collimation of single-mode and multi-mode optical fibers and laser diodes.

A 0.23-pitch lens images a point source placed in the working distance s into infinity or collimates it (see Fig. 3).

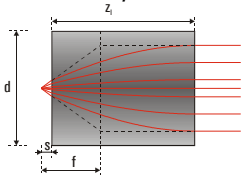


Fig. 3. GRIN rod lens

The geometrical gradient constant g and the lens length z_l determines the focal length f and the working distance s of the lens,

$$f = \frac{1}{n_0 g \sin(gz_l)}, \qquad s = \frac{1}{n_0 g \tan(gz_l)}$$

Various imaging problems can be solved by choosing different lens lengths z_l (see Fig.4).

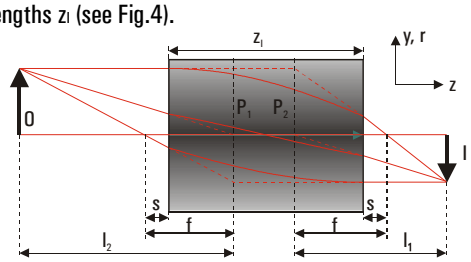


Fig. 4. Image formation by a GRIN focusing lens

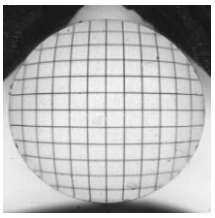
The maximum acceptance angle of a GRIN collimating lens ϑ is determined by the numerical aperture NA. As in fiber optics, it is derived from the maximum index change of the GRIN profile,

$$\sin(\vartheta) = NA = \sqrt{n_0^2 - n_R^2} = n_0 \sqrt{1 - \mathrm{sech}^2(gd/2)}\ .$$

n_R is the refractive index at the margin of the profile, and d is the lens diameter or the lens thickness, respectively.
GRIN lenses with a high numerical aperture (NA ≈ 0.5) are produced by silver ion exchange in a special glass which avoids any coloration in the visible spectral range. The absorption edge of the silver containing glass occurs at a wavelength of $\lambda_{0.5}$ = 370 nm. GRIN lenses with low numerical aperture (NA ≤ 0.2) are fabricated via lithium ion exchange. The absorption edge of the glass being used is at a wavelength of $\lambda_{0.5}$ = 235 nm.

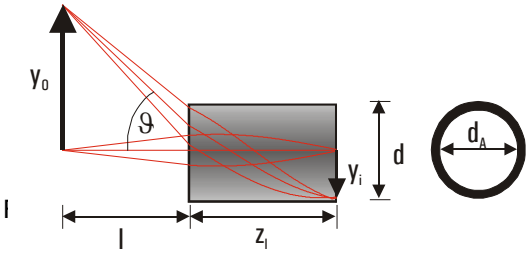
Gradient Index Imaging Optics

- GRIN rod lenses and systems
- endoscopic and other miniaturized imaging applications
- easy to assemble due to the plane surfaces
- good off- and on-axis performance
- AR-coating on both sides possible
- non-toxic silver and lithium ion exchange
- low chromatic aberration



GRIN Objective Design

GRINTECH objective lenses are produced by non-toxic silver ion exchange in glass and are suited for medical applications. The large view angle of 60 degrees (± 30°) is obtained by a strong index change within the glass material. The objective lenses image the object plane in a working distance l (see Fig. 1) into the end surface of the lens on a reduced scale.



The lenses are specified by the rod diameter d and the working distance l (see the respective data sheet). The corresponding magnification M and the necessary lens length z_l are calculated by

$$M = \sqrt{\frac{1}{n_0^2\, g^2\, l^2 + 1}} \quad ; \quad z_l = \frac{\arctan(-n_0\, l\, g) + \pi}{g},$$

where n_0 is the center index of the lens, and g is the gradient constant of the lens. For each diameter, g can be calculated by using the lens length of the respective lens type with infinite working distance,

$$g = \frac{\pi}{2 z_l^{inf}}.$$

Beside standard working distances, customized lens designs can be provided on request.

The dispersion of the index gradient causes a relative change of the focal length as function of the wavelength. In the visible range, the focal length of lenses with NA of 0.5 increases by approx. 0.017 % per nm with rising wavelength. For objective lenses of 1.0 mm diameter, the image plane of the blue light part (440 nm) is located approx. 18 μm inside the lens. The image plane of the red light part (650 nm) is located approx. 18 μm outside the lens exit plane. For lenses of 0.5 mm diameter for example, half of these image shift values is valid.

GRINTECH objective lenses are characterized by a small field curvature. The image field is slightly bent inwards. For lenses of 1.0 mm diameter the field curvature is – 40 μm maximum at 90 % of the aperture, for 0.5 mm diameter – 20 μm maximum.

The barrel shaped distortion of the image increases up to approx. 14 % of the image height at the lens margin (see CCD-image above).

The resolution limit of the objective lenses is on-axis approx. 400 lines per mm in white light.

GRIN Imaging Systems

Complete imaging systems for endoscopes and other applications are fabricated by combining GRINTECH objective lenses, GRIN relay lenses of customized pitch lengths, and prisms. Please contact GRINTECH for customized solutions.

Contact

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