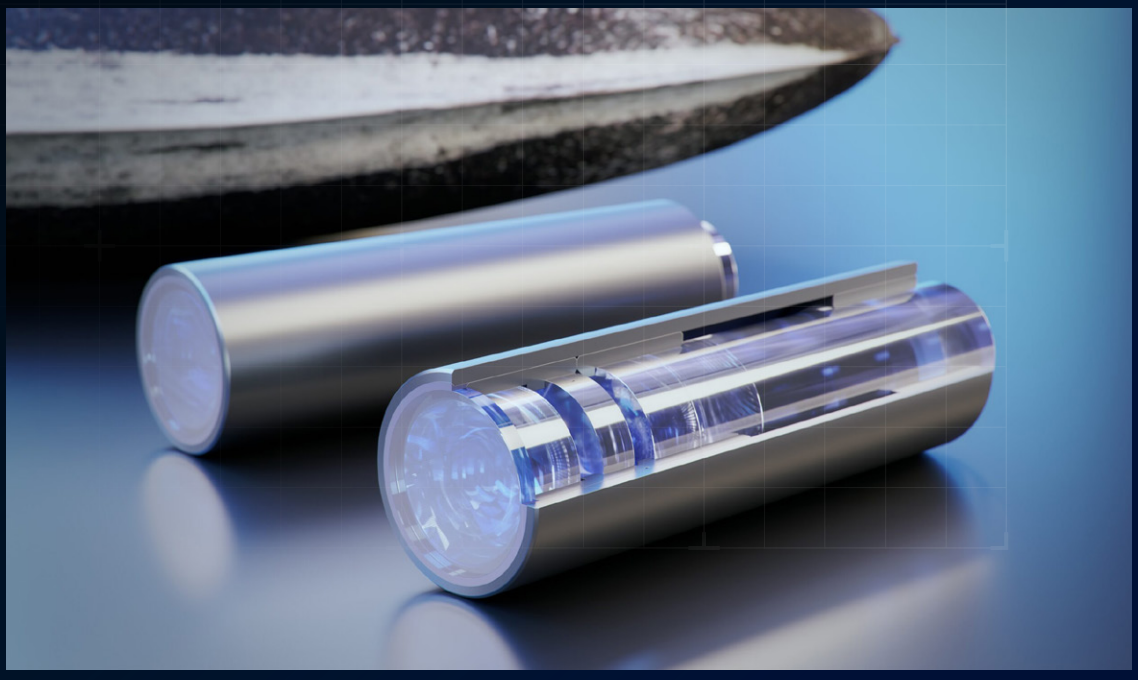
# GRINTECH

*Gradient Index Optics*

# Miniature High-NA Objectives



www.grintech.de

# High-performance miniature objectives – *compact* and *versatile*

GRIN Needle Endomicroscopes (GRIN singlets and doublets) provide a unique and uncomplicated microscopic access with minimal invasiveness to deep tissue regions, especially as consumables. However, if numerical apertures greater than 0.6 (NA > 0.6) are required, or the field of view of pure GRIN lenses with high resolution is not sufficient, or chromatic aberration needs to be corrected over a wide spectral range, miniature high-NA objectives with diameters of 1.3 to 2.2 mm provide the solution for your needs.

The different product versions differ in their complexity and thus also in the degree of correction of aberrations.

In 2009, GRINTECH has introduced the ***SpheroCor*** high-NA objectives with only 1.4 mm diameter, which increase the Numerical Aperture from 0.55 to 0.8 by a combination of GRIN lenses with plano-convex micro-lenses, which correct spherical aberration on-axis and significantly improve the resolution to image, for example, dendritic spines *in vivo* for neuroscientists [Barretto, R., Messerschmidt, B. & Schnitzer, M. *In vivo* fluorescence imaging with high-resolution microlenses. Nat Methods 6, 511–512 (2009)]. https://doi.org/10.1038/nmeth.1339]. However, chromatic aberration is not corrected and the field of view is limited in these least complex objectives.

Since 2016, GRINTECH offers the ***FieldAchromatic*** high-NA objectives. With a diameter of only 1.3 mm, they provide a tremendously increased field of view of up to 400 µm in tissue with sub-micron resolution due to the high NA of 0.7 – 0.8. This field correction is combined with a very broad correction of lateral and axial chromatic aberration from 488 to 900 nm, making these objectives the perfect optics for non-linear fiber-scanning endoscopes or coherent fiber bundle based endomicroscopic probe heads. Offering these high NA's, a large field of view and small component diameter results in a stronger field curvature of up to 20 – 28 µm focus shift at the marginal field of view, which is often accepted when diagnosing volume tissues. A special version of the ***FieldAchromatic*** Series is the 178 mm long endomicroscopic tube for CARS endomicroscopy providing a chromatic correction from 795 nm to 1029 nm.

In 2023, GRINTECH brought the ***ReduCurv*** high-NA objectives with diameters of 1.3 and 2.2 mm on the market, the latest generation which offers additionally a significant 70% reduction of field curvature in object space, while keeping high NA, large field of view and sub-micron resolution. Focus shifts from the center to the margin of the field of view are reduced to only 6 – 7 µm. These objectives are recommended for imaging of planar and very thin samples or where a very flat field of view is required.

## *We support* you with your specific needs:

On request, we advise you for the best solution in your specific application:

- *In vivo* endomicroscopy, single-photon fluorescence microscopy
- Nonlinear Optical Imaging Modalities (SHG, TPF)
- Tissue imaging, flexible fluorescence microscopy
- NA Conversion

# *SpheroCor* High-NA Endomicroscopic Imaging Objective for 2-Photon Microscopy

GRINTECH's *SpheroCor* high-NA Endomicroscopic Imaging Objectives cascade the optical power of a plano-convex lens and a GRIN lens with spherical aberration compensation to achieve an object NA of 0.8. This first 2009 generation of high NA objectives provides superior resolution of sub-micron details as dendritic spines, for example [Barretto, R., Messerschmidt, B. & Schnitzer, M. *In vivo* fluorescence imaging with high-resolution microlenses. Nat Methods 6, 511–512 (2009)].

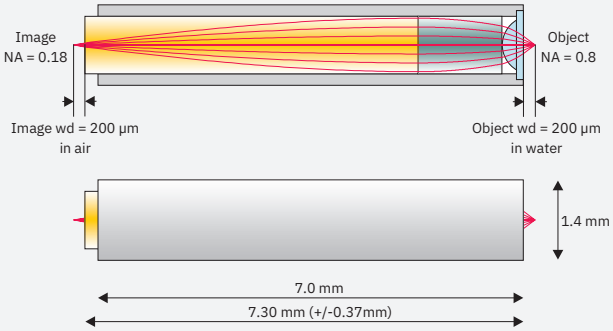
### Applications

- *In vivo* endomicroscopy
- 2-photon microscopy
- Deep brain and tissue imaging
- Flexible fluorescence microscopy
- NA conversion

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

**Features:**

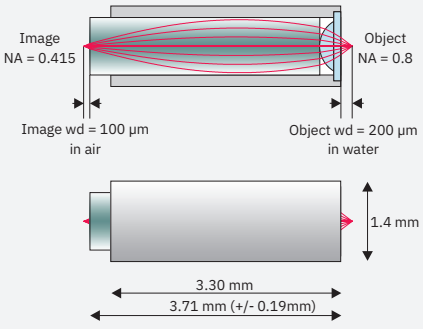
- Object NA = 0.80
- Object working distance 200 µm (water)
- Image NA = 0.18
- Magnification 4.8 ×
- Recommended Excitation 800 – 1000 nm
- Mounted in stainless steel holder




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

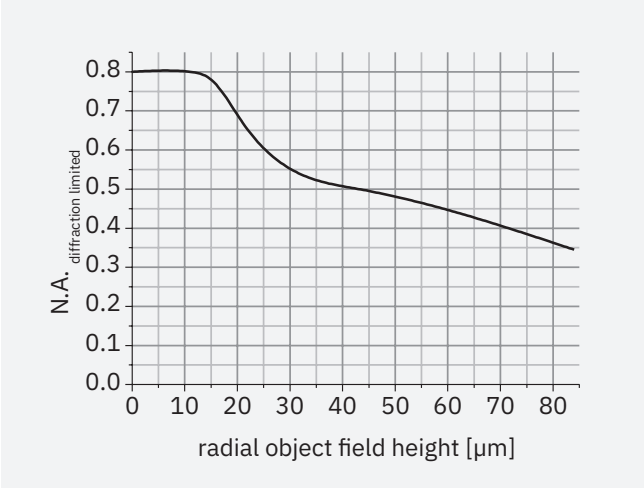
**Features:**

- Object NA = 0.80
- Object working distance 200 µm (water)
- Image NA = 0.415
- Magnification 1.92 ×
- Recommended Excitation 800 – 1000 nm
- Mounted in stainless steel holder



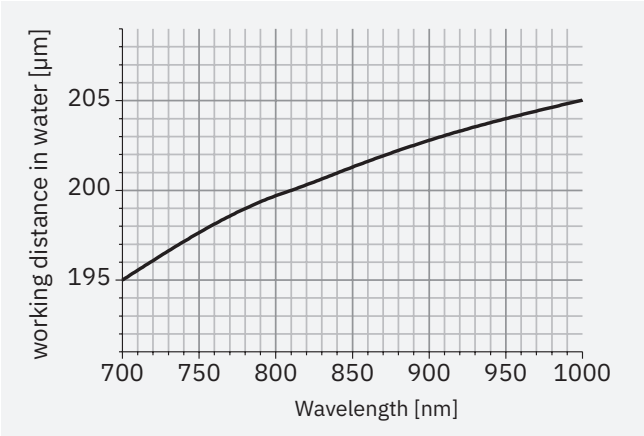
## Product Code: GT-MO-080-018-810

### Diffraction limited NA versus Field



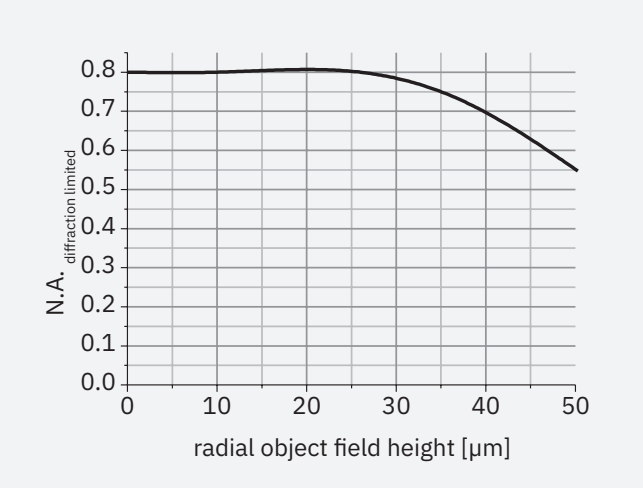

From optical design simulation according to Marechal criterion @ 810 nm, wavefront RMS ≤ 0.07 λ

### Chromatic Aberration in Object Space



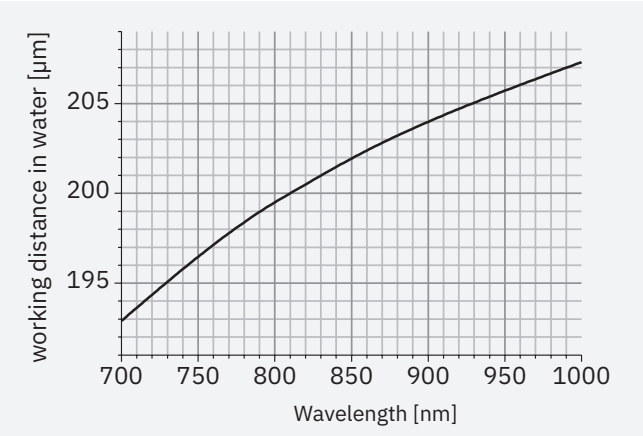

## Product Code: GT-MO-080-0415-810

### 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 the end of this brochure.

# *SpheroCor* High-NA Endomicroscopic Imaging Objective for Fluorescence Microscopy

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

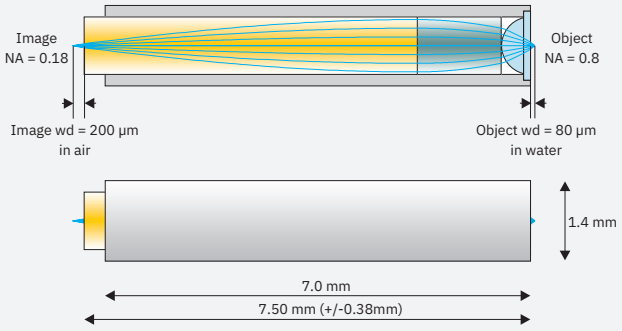
### Applications

- *In vivo* endomicroscopy
- Fluorescence microscopy
- Tissue imaging
- Flexible fluorescence microscopy
- NA conversion

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

**Features:**

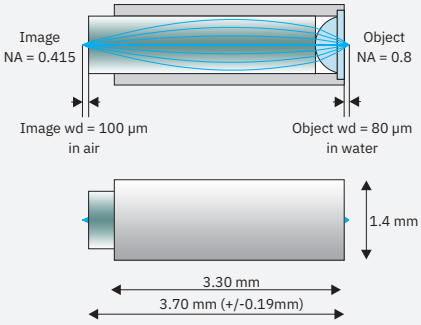
- Object NA = 0.80
- Object working distance 80 µm (water)
- Image NA = 0.18
- Magnification 4.65 ×
- Recommended Excitation 488 nm
- Mounted in stainless steel holder




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

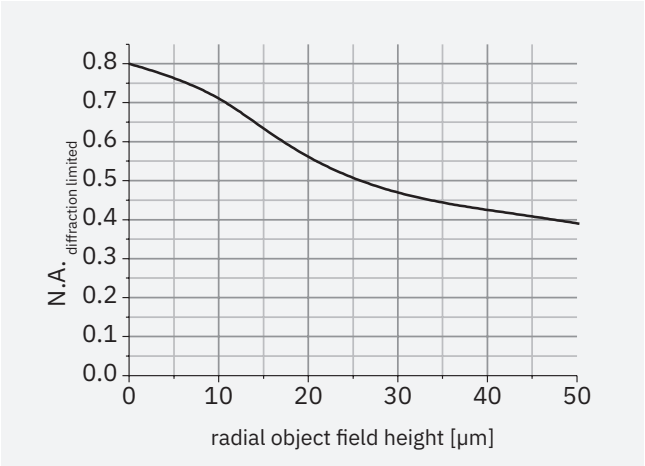
**Features:**

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



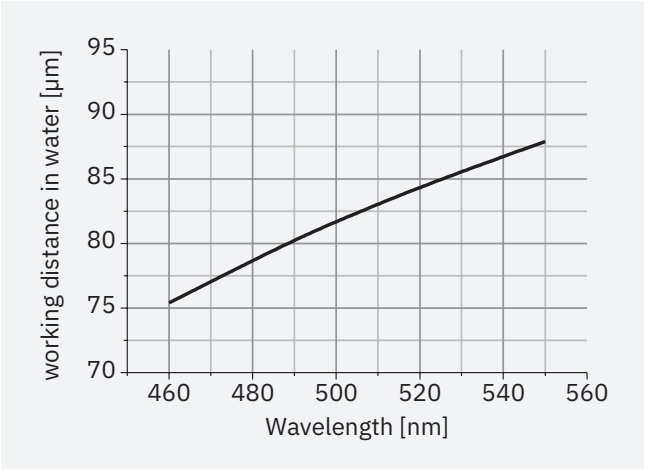
## Product Code: GT-MO-080-018-488

### Diffraction limited NA versus Field



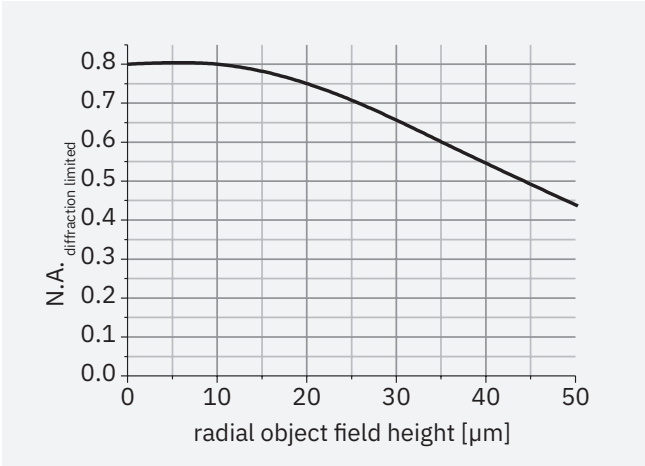

From optical design simulation according to Marechal criterion @ 488 nm, wavefront RMS ≤ 0.07 λ

### Chromatic Aberration in Object Space



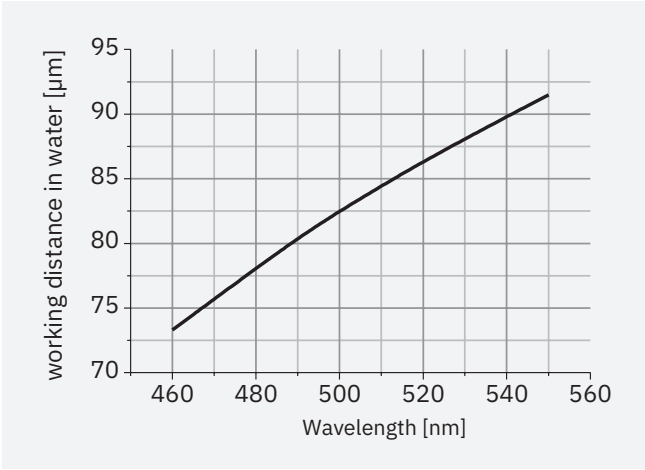

## Product Code: GT-MO-080-0415-488

### 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

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# *FieldAchromatic* High-NA chromatic and field corrected Endomicroscopic Imaging Objectives

GRINTECH's *FieldAchromatic* 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.

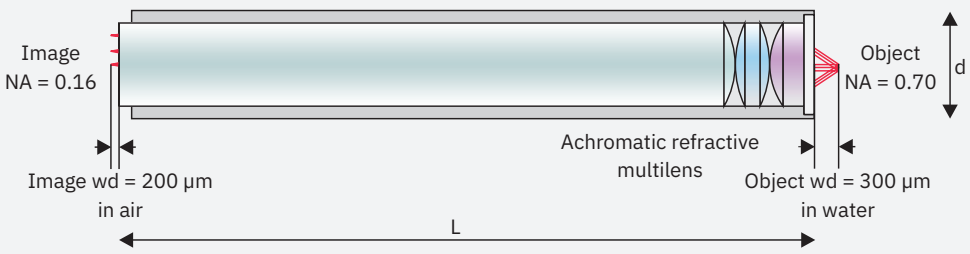
**GT-MO-070-016-ACR-VISNIR-30-20** is optimized for wavelengths of 450 nm and 900 nm to achieve an ideal performance in SHG and TPF applications within a large field of view.

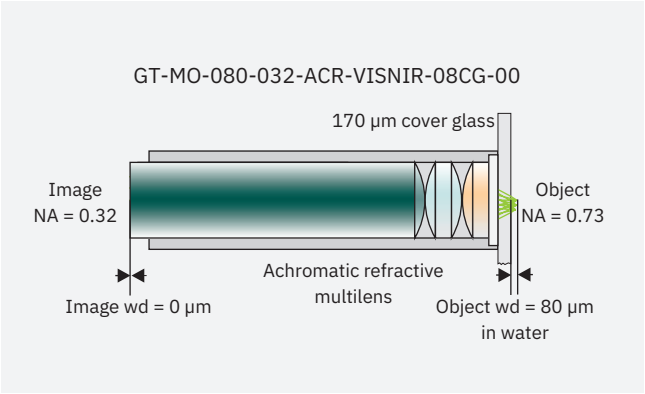
Four combinations of proximal and distal working distances are offered as listed below in the first 4 columns:

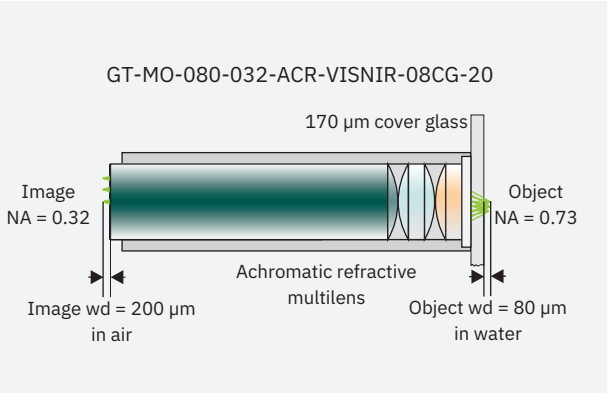
| **GT-MO-080-032-ACR-VISNIR-...** | **...08CG-00** | **...08CG-20** | **...08-00** | **...08-20** | **GT-MO-070-016-ACR-VISNIR-30-20** |
|---|---|---|---|---|---|
| **Object NA** | 0.73 | 0.73 | 0.79 | 0.79 | 0.7 |
| **Object WD in water** (µm) | 80 | 80 | 80 | 80 | 300 |
| **Designed for cover glass** (µm) | 170 | 170 | none | none | none |
| **Image NA** | 0.32 | 0.32 | 0.32 | 0.32 | 0.16 |
| **Image WD in air** (µm) | 0 | 200 | 0 | 200 | 200 |
| **Magnification** | 2.2* | 2.2* | 2.4* | 2.4* | 4.4 |
| **Dimensions ø / L** (mm) | 1.3 / 4.89 | 1.3 / 4.57 | 1.3 / 5.02 | 1.3 / 4.7 | 1.3 / 8.36 |

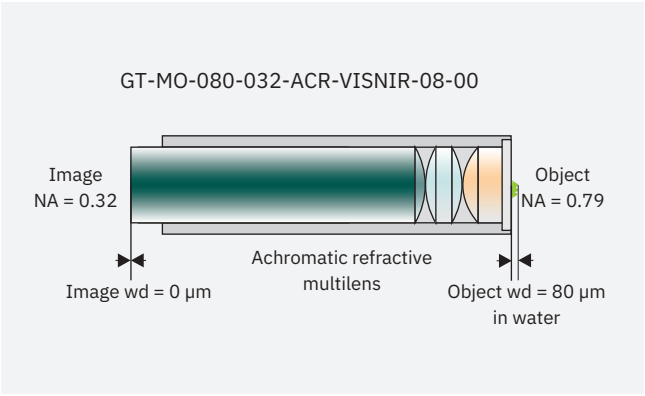
* depending on Image NA

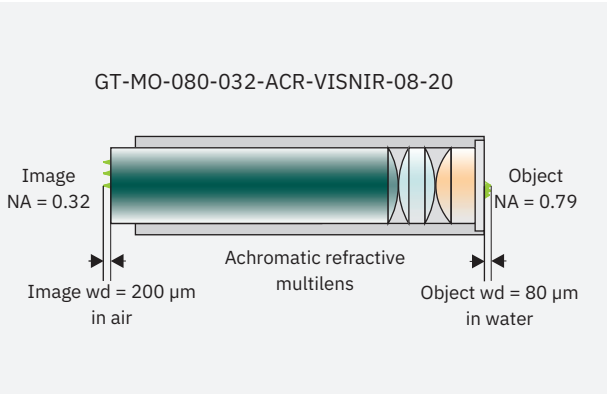
GT-MO-070-016-ACR-VISNIR-30-20



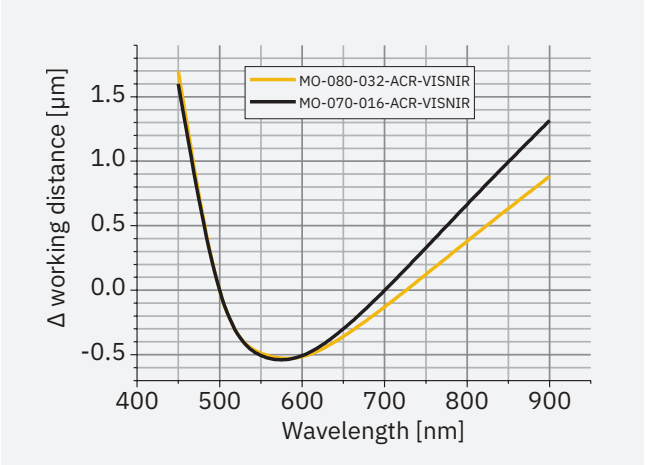


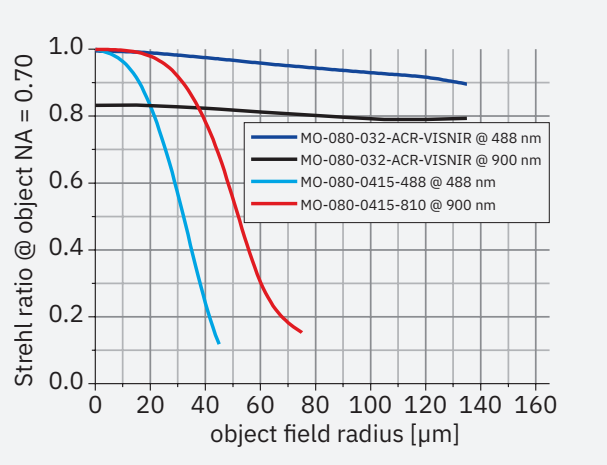




**Chromatic Aberration in Object Space**




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

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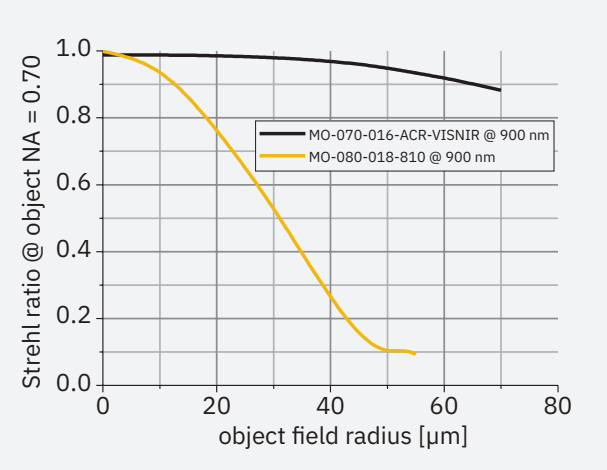


# *FieldAchromatic* High NA chromatic and field corrected Endomicroscopic Imaging Objectives

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

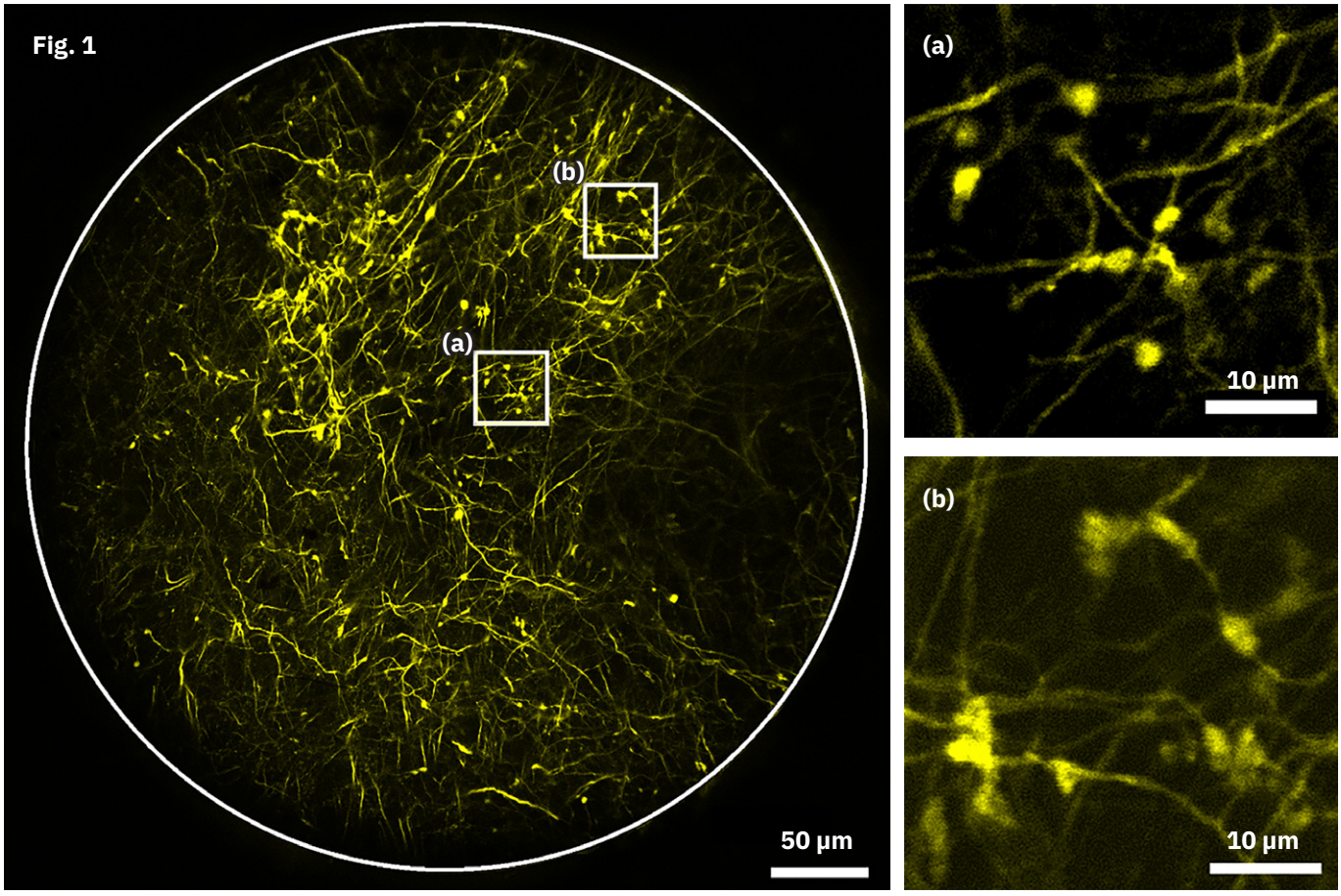



**Fig.1:** Mouse brain section, PFA fixation, cover glass 170 µm confocally imaged in fluorescence (exc. 488 nm) with **GT-MO-080-032-ACR-VISNIR-08CG-00** coupled to Olympus FV1000 with MO 10×; NA=0.4 with XYZ-Stage. White circle shows backside aperture of 1 mm corresponding to full object FOV of 450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

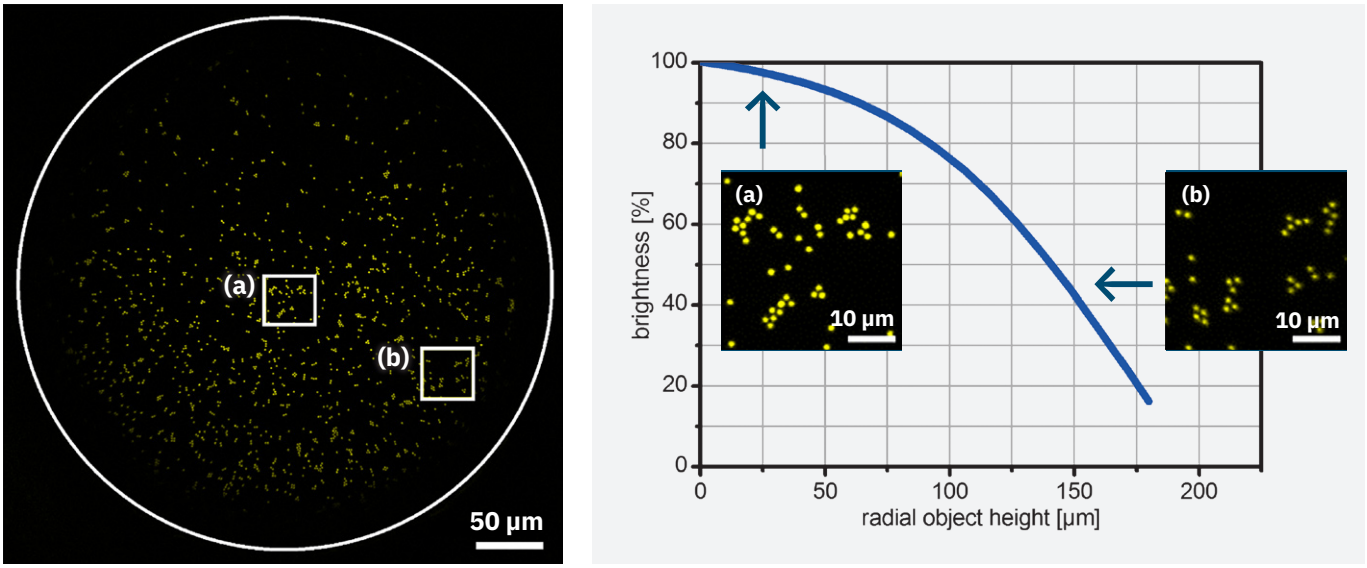



**Fig.2:** fluorescence beads with Ø=2µm yellow/green acquired with **GT-MO-080-032-ACR-VISNIR-08-00**. Right: bead brightness depending on the radial object height. (a) and (b) 40 µm × 40 µm sections from the center and edge of object FOV.

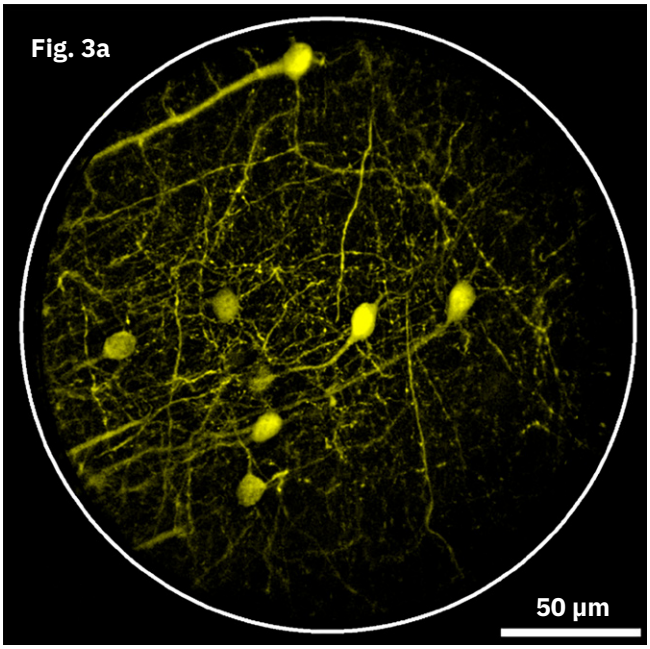



**Fig.3a: GT-MO-070-016-ACR-VISNIR-30-20** with full object FOV of 200 µm (optimal imaging in 150 µm) compared to Fig.3b.

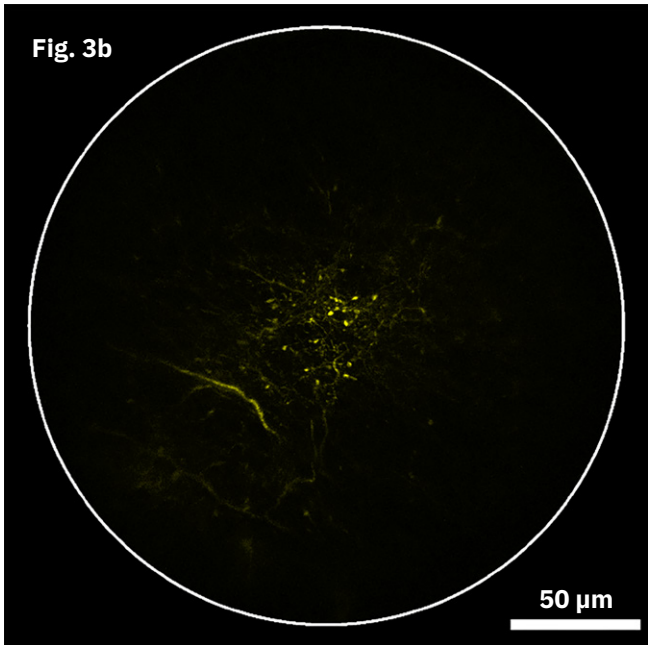



**Fig.3b: GT-MO-080-018-AC900-450** with FOV of 65 µm (not offered anymore)

The usable field of view is increased to 300% in diameter compared to previous *SpheroCor* objectives. Now available also in 1.3 mm outer diameter instead of 1.4 mm. For more details, please contact GRINTECH.

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

GRINTECH's *FieldAchromatic* 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

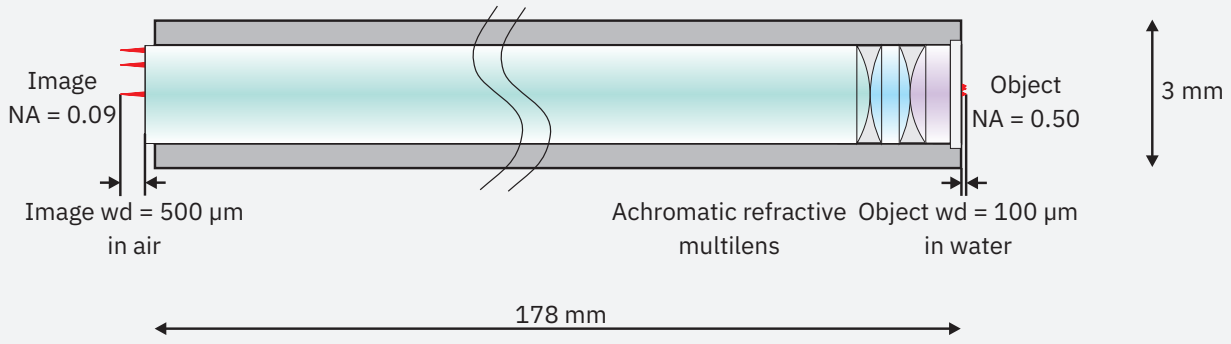
**GT-MO-050-009-ACR795/1029-10-50** represents a high resolution field- and NIR-chromatically corrected objective with a magnification of 5.6. The image side NA of 0.09 matches to low NA telecentric spot scanning. Chromatic correction is realized between 795 nm to 1029 nm together with an optimal performance.

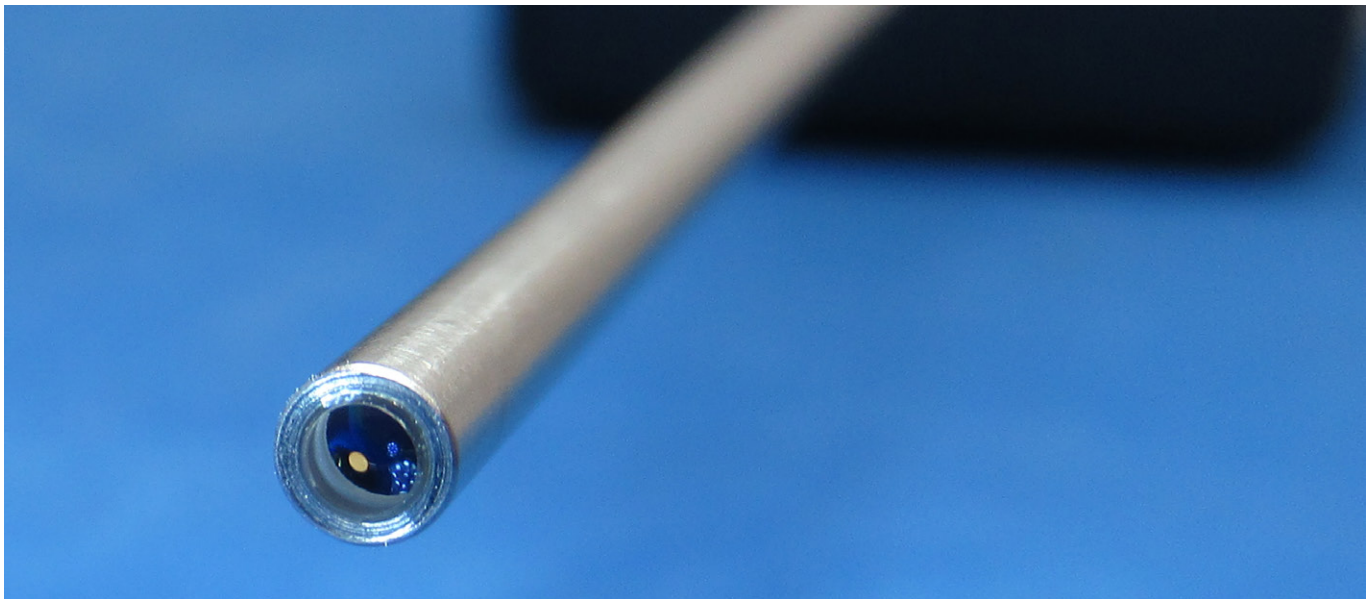
The optics is assembled in a stainless steel tube of 3.0 or 2.2 mm diameter (optional).

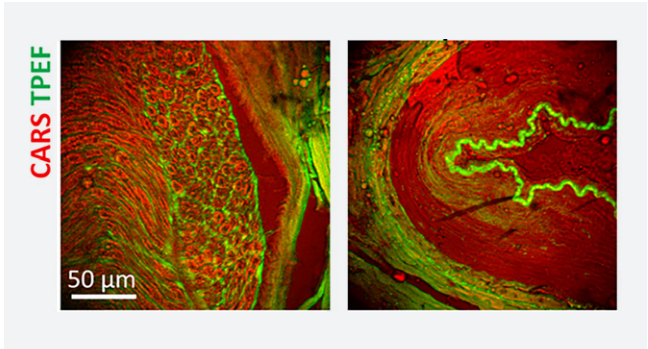
### Specifications

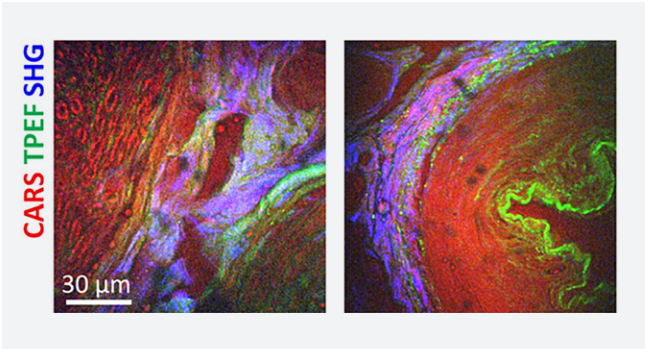
| GT-MO-050-009-ACR795/1029-10-50 | |
|---|---|
| **Object NA** | 0.50 |
| **Object WD in water** (µm) | 100 |
| **Image NA** | 0.09 |
| **Image WD in air** (µm) | Approx. 500 |
| **Magnification** | 5.6 |
| **Dimensions ø / L** (mm) | 3.0 or 2.2 / 178 |

**GT-MO-050-009-ACR795/1029-10-50 schematic with dimensions**








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 handling and storage see the end of this brochure.

# *ReduCurv* High-NA chromatic and field corrected Endomicroscopic Imaging Objectives with reduced curvature (NA 0.7, 2.2 mm diameter)

GRINTECH's 2023 variant of *ReduCurv* high-NA Endomicroscopic Imaging Objectives provide 70% reduced field curvature (compared to *FieldAchromatic* objectives) while offering object Numerical Apertures of 0.7 in a broad achromatic and field correction. These objectives are recommended for imaging of planar and very thin samples or where a very flat field of view is required.

### Applications

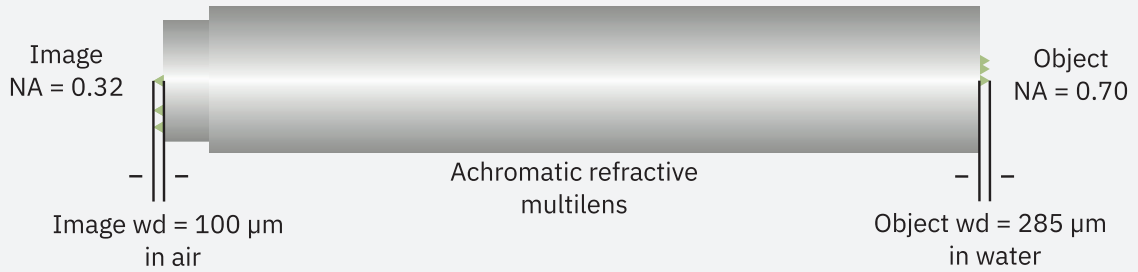
- *In vivo* endomicroscopy
- Single photon fluorescence microscopy
- Nonlinear optical imaging modalities (SHG, TPF)
- Tissue imaging
- Flexible fluorescence microscopy
- NA conversion, especially all applications to image thin and planar samples or where a flat field of view is required

**GT-MO-070-032-ACR-VISNIR-REDUCURV-28-10** represents high resolution field and color corrected objectives with a magnification of 2.2. The image side NA of 0.32 matches to imaging fiber bundles. Color correction is achieved from 450 nm to 900 nm with an optimal performance from 488 nm to 900 nm. The objectives are assembled in stainless steel mounts.

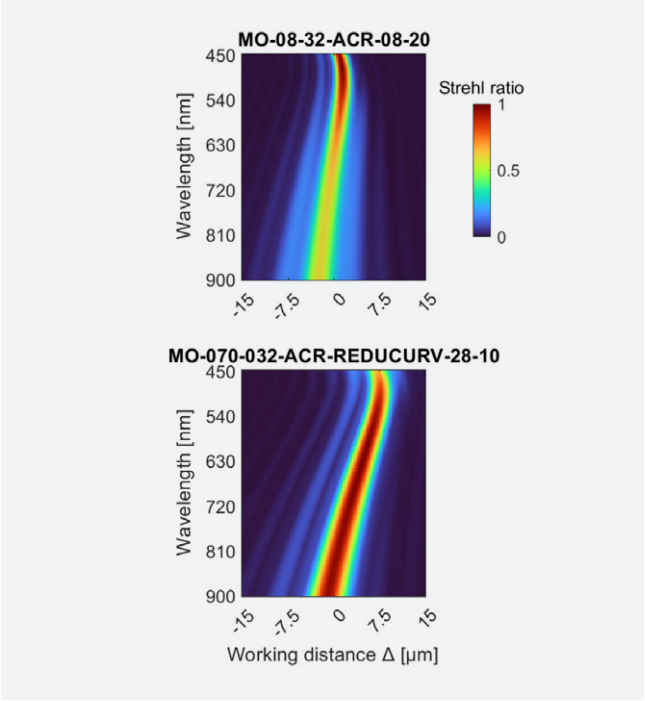
The *ReduCurv* micro objective type with reduced field curvature is offered so far as a version for usage without cover glass. Please compare specs with our *FieldAchromatic* series in the following table and note the different mechanical dimensions.

| | **GT-MO-070-032-ACR-VISNIR-REDUCURVE-28-10** | **GT-MO-080-032-ACR-VISNIR-08-20 (for comparison)** |
|---|---|---|
| **Object NA** | 0.70 | 0.79 |
| **Object WD in water** (µm) | 285 | 80 |
| **Designed for cover glass** (µm) | none | none |
| **Image NA** | 0.32 | 0.32 |
| **Image WD in air** (µm) | 100 | 200 |
| **Magnification** | 2.2 | 2.3 |
| **Field curvature radius** (mm) | 2 | 0.55 |
| **Dimensions ø / L** (mm) | 2.2 / 13 | 1.3 / 4.7 |

**GT-MO-070-032-ACR-VISNIR-REDUCURV-28-10**

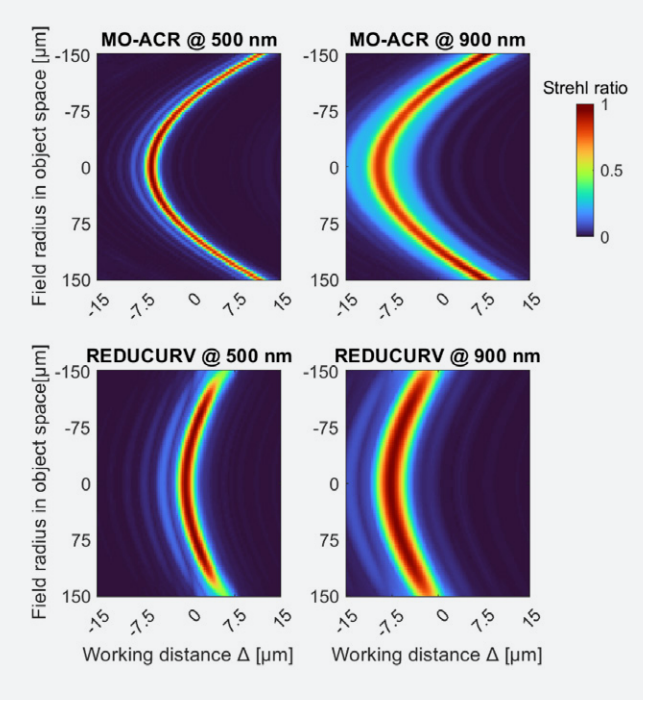


## Chromatic Aberration in Object Space




upper part: *FieldAchromatic* version (for comparison), lower part: *Reducurv* objective

## Field Dependent Strehl Ratio in Object Space




upper part: *FieldAchromatic* version (for comparison), lower part: *Reducurv* objective

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 handling and storage see the end of this brochure.

More information can be found here: Stark, S. L., *et al.* (2023). "Field curvature reduction in miniaturized high numerical aperture and large field-of-view objective lenses with sub 1 µm lateral resolution." Biomedical Optics Express 14(12).

# *ReduCurv* High-NA chromatic and field corrected Endomicroscopic Imaging Objectives with reduced curvature (NA 0.5, 1.2 mm diameter)

GRINTECH's 2023 variant of *ReduCurv* high-NA Endomicroscopic Imaging Objectives with object Numerical Apertures of 0.5 provide 70% reduced field curvature (compared to *FieldAchromatic* objectives) combined with a broad achromatic and field correction. These objectives are recommended for imaging of planar and very thin samples or where a very flat field of view is required.

### Applications

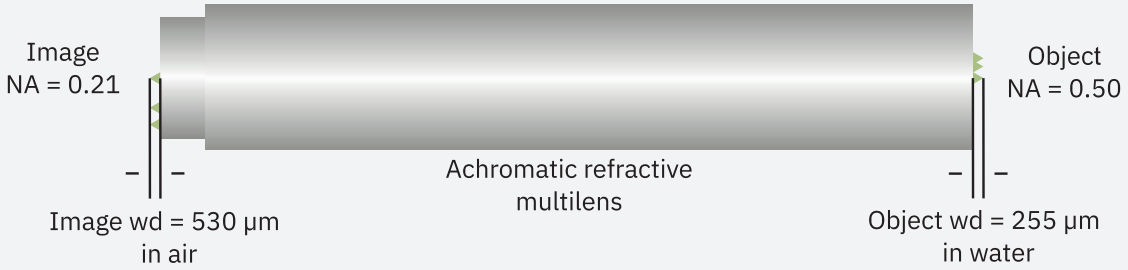
- *In vivo* endomicroscopy
- Single photon fluorescence microscopy
- Nonlinear optical imaging modalities (SHG, TPF)
- Tissue imaging
- Flexible fluorescence microscopy
- NA conversion, especially all applications to image thin and planar samples or where a flat field of view is required

**GT-MO-050-021-ACR-VISNIR-REDUCURV-25-53** features a diameter of 1.2 mm with NA = 0.5. The image side NA is in this case 0.21. Color correction is achieved from 450 nm to 900 nm with an optimal performance from 488 nm to 900 nm. The objectives are assembled in stainless steel mounts.

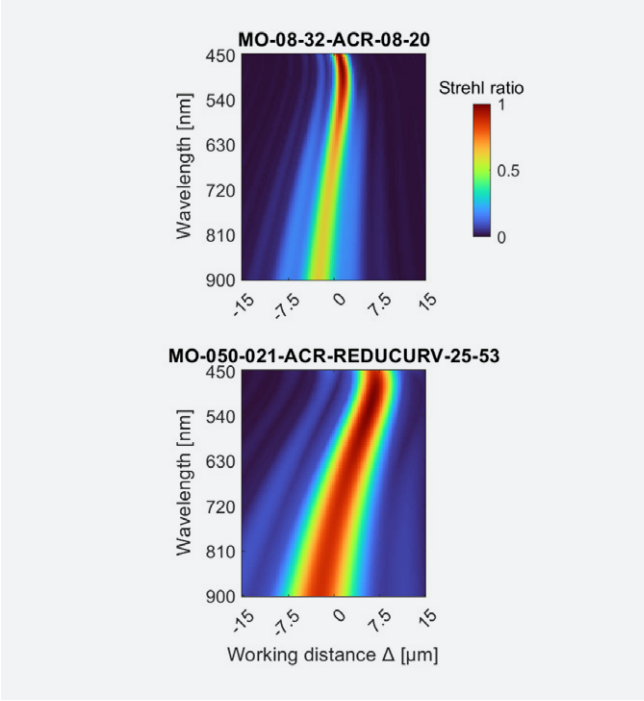
The *ReduCurv* micro objective type with reduced field curvature is offered so far as a version for usage without cover glass. Please compare specs with our *FieldAchromatic* series in the following table and note the different mechanical dimensions.

| | **GT-MO-050-021-ACR-VISNIR-REDUCURV-25-53** | **GT-MO-080-032-ACR-VISNIR-08-20** |
|---|---|---|
| **Object NA** | 0.50 | 0.79 |
| **Object WD in water** (µm) | 255 | 80 |
| **Designed for cover glass** (µm) | none | none |
| **Image NA** | 0.21 | 0.32 |
| **Image WD in air** (µm) | 530 | 200 |
| **Magnification** | 2.3 | 2.3 |
| **Field curvature radius** (mm) | 2 | 0.55 |
| **Dimensions ø / L** (mm) | 1.2 / 5.0 | 1.3 / 4.7 |

**GT-MO-050-021-ACR-VISNIR-REDUCURV-25-53**

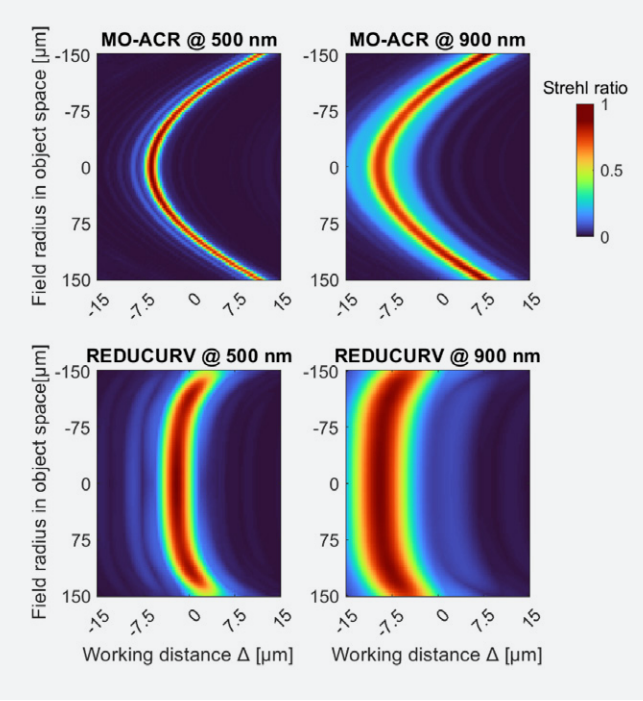


## Chromatic Aberration in Object Space




upper part: *FieldAchromatic* version (for comparison), lower part: *Reducurv* objective

## Field Dependent Strehl Ratio in Object Space




upper part: *FieldAchromatic* version (for comparison), lower part: *Reducurv* objective

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 handling and storage see the end of this brochure,

# Handling and Storage Instructions

## 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.

## Notes

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*Gradient Index Optics*

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