AdlOptica

foXXus_NA0.38

(L9333, L9344)

Multi-focus objective

Manual

October 18, 2021

foXXus 0.07-0.22_NA0.38
foXXus 0.01-0.03_NA0.38

Fig.1 foXXus_NA0.38 objective outlook

1. Specifications

Common for all foXXus_NA0.38 models:		
Description		Objective lens with multiple foci
Accessories		• Window in Holder L9333.04 • Protective Window D12 @operating wavelength • Spanner Wrench K-20.2-0.4x0.4 • Waveplate in Holder L9333.05 + Window in Holder L9333.06
Clear Aperture, mm		12.9
Numerical aperture (NA)		0.38 (by input beam diameter 12.9 mm)
2ω, μm waist in air, by Gaussian beam of 1/e^2 diameter 9 mm	1030 nm	2.5
	515 nm	1.3
	343 nm	0.9
Angular field of view		± 1°
Recommended maximum pulse energy		25 mJ at 5 ns
Mounting		C-Mount (1”-32 UN 2A)
Diameter, mm		34
Length, mm		<39 (37.5 mm – 39 mm depending on the Implementation)

foXXus_NA0.38 features:

Model	Focal length, mm	Spectral band, nm	ΔF* – distance between foci, μm				WD**, mm
			2 foci		4 foci		
			air	glass (x1.5)	air	glass (x1.5)	
0.07-0.22_NA0.38_1030	17	1020-1080	72, 220	110, 338	74 - 72 - 74	114 - 110 - 114	9.7
0.07-0.22_NA0.38_515/1030	17	510-540 1020-1080	72, 220	110, 338	74 - 72 - 74	114 - 110 - 114	9.7
0.07-0.22_NA0.38_343/515	17	335-365 510-540	72, 220	110, 338	74 - 72 - 74	114 - 110 - 114	9.7
0.01-0.03_NA0.38_1030	16.3	1020-1080	10, 30	15, 45	10 - 10 - 10	15 - 15 - 15	12
0.01-0.03_NA0.38_515/1030	16.3	510-540 1020-1080	10, 30	15, 45	10 - 10 - 10	15 - 15 - 15	12

* - See detailed data in separate tables,

** - WD - Working Distance from mechanical face of objective, is shortened:

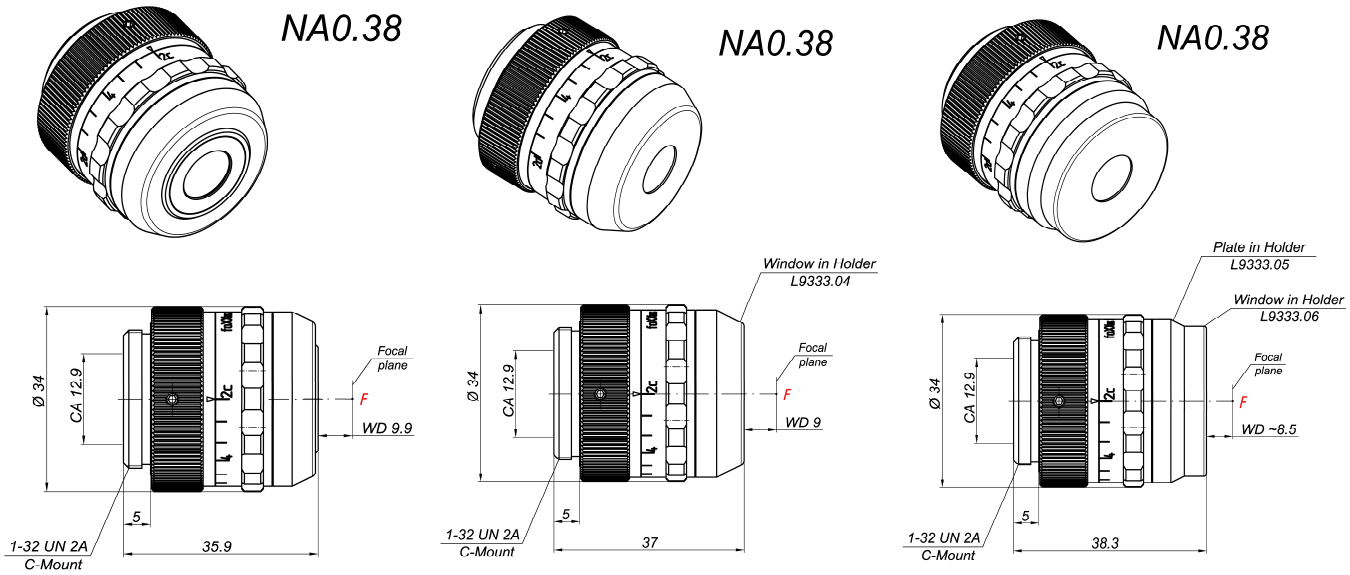
- at 1 mm by implementation Objective + Window in Holder L9333.04,
- at 2.2 mm by implementation Objective + Waveplate in Holder L9333.05 + Window in Holder L9333.06.

2. Description

Important! Current versions L9333 of **foXXus 0.07-0.22_NA0.38** is completely compatible with previous version L9322:

- the same optical design,
- near same overall dimensions with adapter installed,
- the same mounting thread C-Mount.

Objectives **foXXus 0.07-0.22_NA0.38** and **foXXus 0.01-0.03_NA0.38**, hereinafter referred to as foXXus, present beam shaping optical devices splitting the light beam in several beamlets in order to focus it in up to 4 separate focuses along optical axis. Operation principle is based on lossless beam transformation, independently from beam size within foXXus clear aperture and parameters of beam quality (any M^2 or BPP). The foXXus objectives are intended to be used with modern ultrashort pulse lasers - design of objectives presumes absence of focusing of partially reflected light ("ghosts") inside lenses, high resistance AR-coatings. This makes the foXXus objectives suitable in applications like cutting of glass, dicing of Al_2O_3, SiC and other brittle materials, where the foXXus provide simultaneous multi-layer processing.
Drawings of two foXXus implementations are presented in Figs.2,3.



(a) (b) (c)

Fig.2 Overall and mounting dimensions:

(a) foXXus with NA0.38

(b) foXXus with Protective Window D12 in Holder L9333.04,

(c) foXXus with Plate in Holder L9333.05 and Protective Window D12 in Holder L9333.06.

3. Controls and Adjustments

The controls and adjustment means are presented in Fig.3:

- Ring “Plate” with Scale “2c – 4 – 2d” to set required combination of foci,
- Fixation Screw – on the Ring “Plate” opposite to mark “4” (not seen).

It is implied 2 steps of adjustment

the **1st step** is
Setting the Ring “Plate” in position “2c” or “4” or “2d” and locking by the Fixation Screw,

the **2nd step** is
Rotating the polarization plane of input beam using external wave plate; the foXXus objective is fixed.

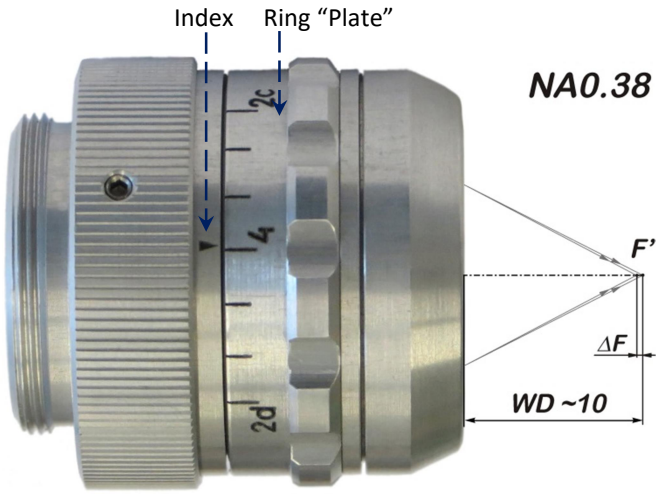


Fig.3 Controls and adjustments.

Settings for foci layouts with even energy portions are presented in Fig.6.

http://www.adloptica.com/pub/foxxus_na038_energy_distribution.xlsx is the Excel-program to calculate the energy portions in the characteristic and intermediate foci layouts.

Energy portions are symbolically depicted by circles of different size.

Notation on the Scale of the Ring “Plate” corresponds to foci-combinations in case of unpolarized light:

- “2c” – 2 close foci,
- “4” – 4 foci,
- “2d” – 2 distant foci.

ΔF is proportional to refractive index of material.
Values of ΔF in air, glass, sapphire and SiC are presented in Tables 1 and 2.

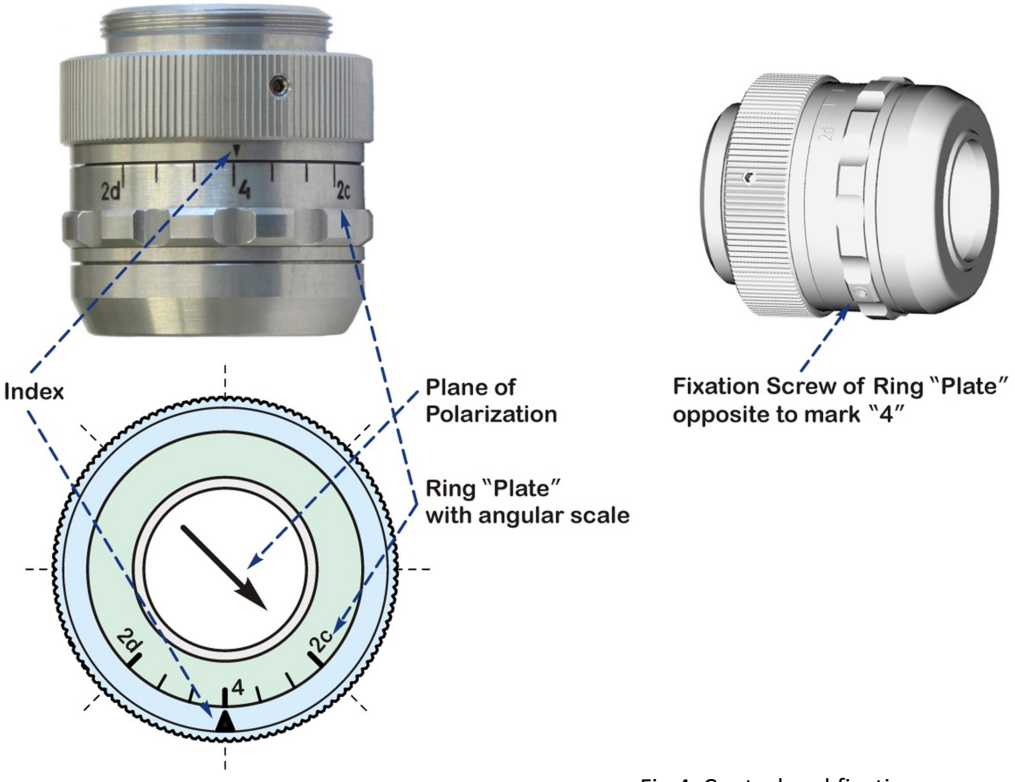


Fig.4 Control and fixation means.

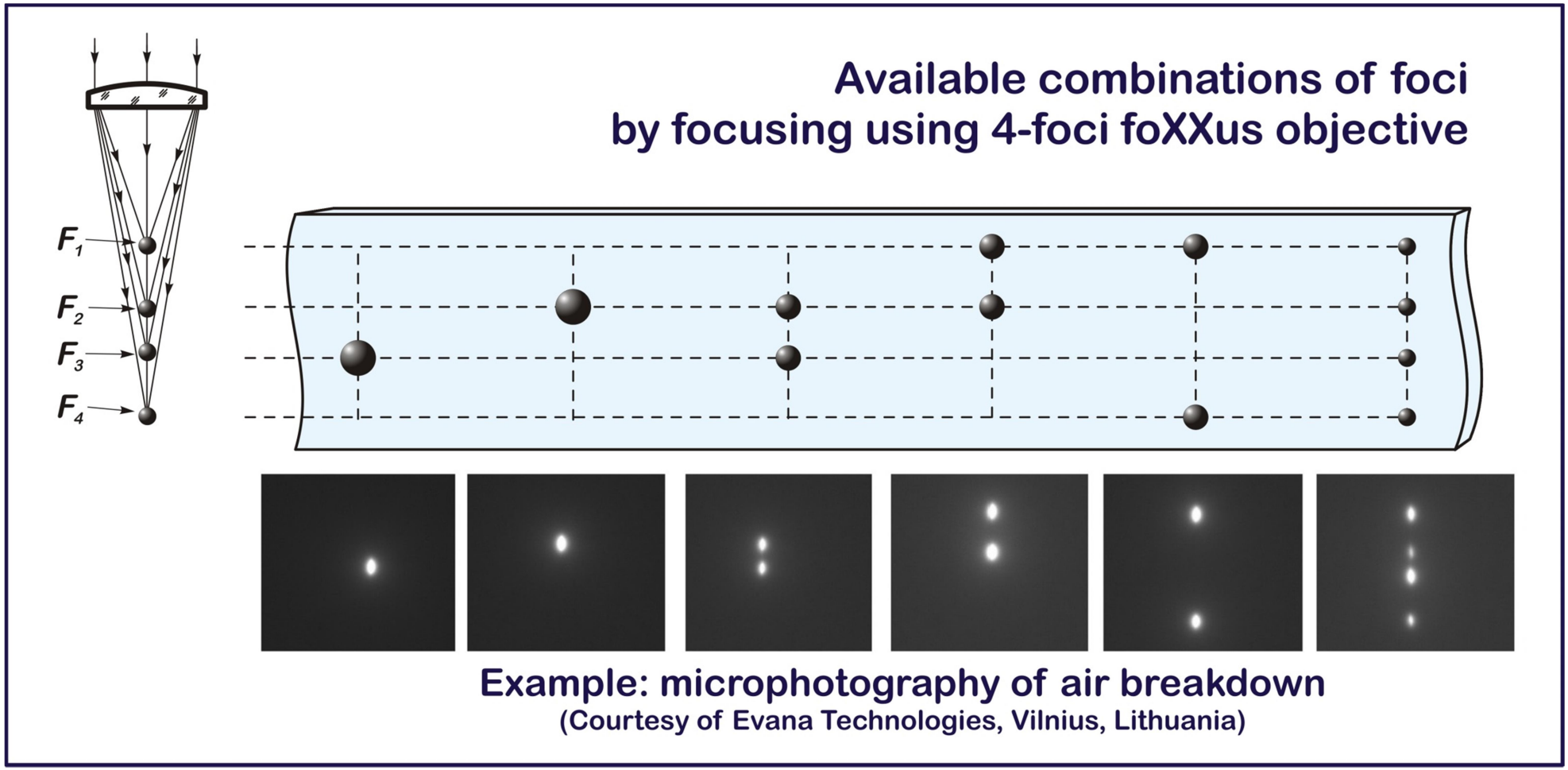


Fig.5 Foci combinations and examples of view of zone of focuses with air breakdown by focusing fs pulses.

4. Table of foci-layouts with even energy portions

also in http://www.adloptica.com/pub/foxxus_na038_energy_distribution.xlsx

NA0.38

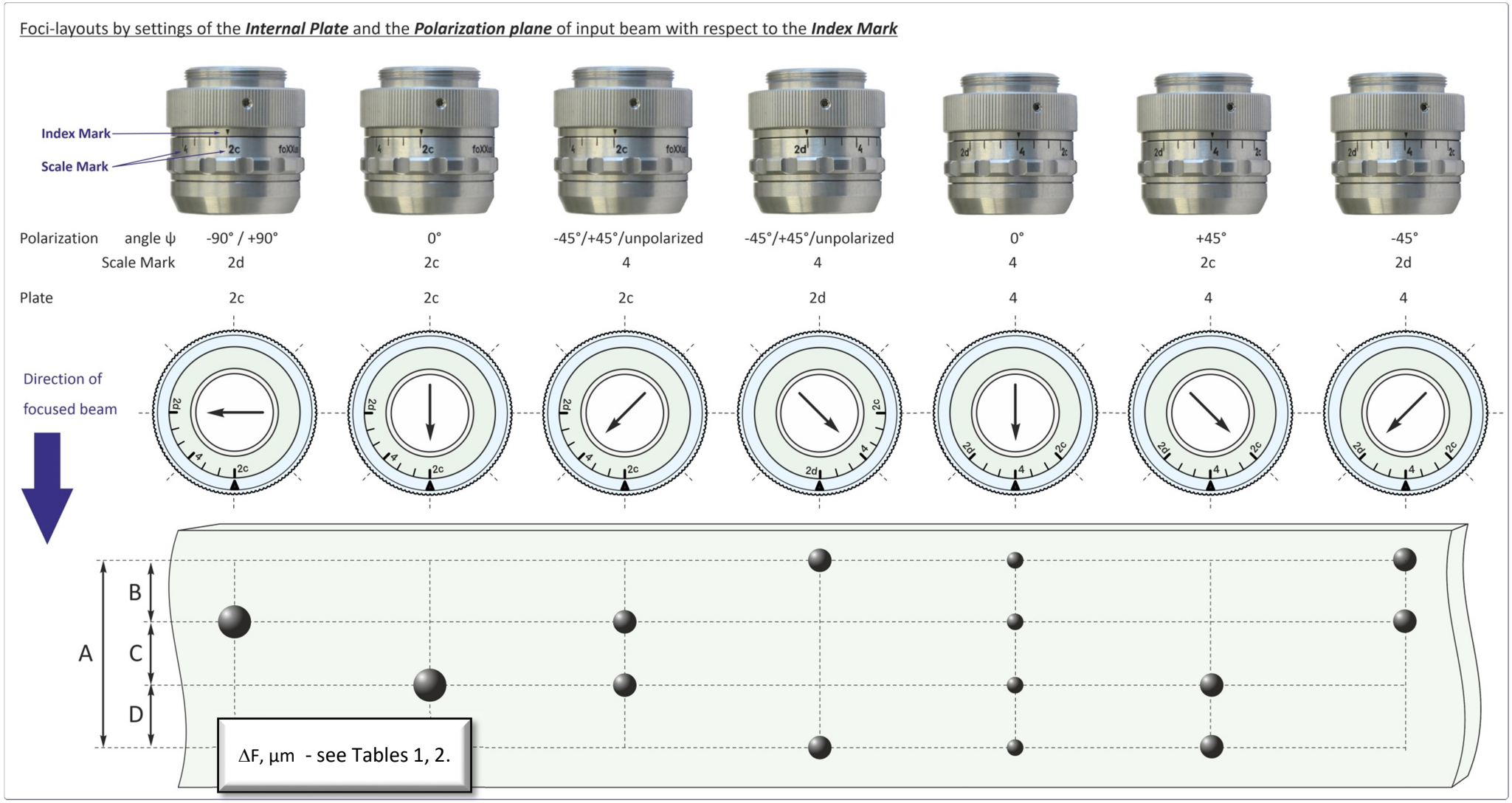


Fig.6 Settings of foXXus and external laser beam for various foci combinations.

5. Distances between foci

foXXus 0.01-0.03_NA0.38 Table 1

λ = 1030 nm					
ΔF, µm	in air	glass N-BK7 (x1.51)	Al_2O_3 (x1.76)	SiC (x2.59)	Si (x3.565)
A	30	45	54	78	108
B	10	15	18	26	36
C	10	15	18	26	36
D	10	15	18	26	36
λ = 515 nm					
ΔF, µm	in air	glass N-BK7 (x1.52)	Al_2O_3 (x1.77)	SiC (x2.68)	Si (x4.21)
A	30	46	54	82	126
B	10	13	16	24	42
C	10	20	22	34	42
D	10	13	16	24	42
λ = 343 nm					
ΔF, µm	in air	glass N-BK7 (x1.54)	Al_2O_3 (x1.80)	SiC (x2.87)	
A	30	46	54	88	
B	10	13	16	25	
C	10	20	23	38	
D	10	13	15	25	

foXXus 0.07-0.22_NA0.38 Table 2

λ = 1030 nm					
ΔF, µm	in air	glass N-BK7 (x1.51)	Al_2O_3 (x1.76)	SiC (x2.59)	Si (x3.565)
A	220	336	391	576	785
B	74	112	131	193	264
C	72	112	130	190	257
D	74	112	131	193	264
λ = 515 nm					
ΔF, µm	in air	glass N-BK7 (x1.52)	Al_2O_3 (x1.77)	SiC (x2.68)	Si (x4.21)
A	221	342	400	603	930
B	74	114	134	201	312
C	73	114	132	201	306
D	74	114	134	201	312
λ = 343 nm					
ΔF, µm	in air	glass N-BK7 (x1.54)	Al_2O_3 (x1.80)	SiC (x2.87)	
A	220	343	401	637	
B	73	114	133	211	
C	74	115	135	215	
D	73	114	133	211	

6. Spectral properties

The optical design of the *foXXus* is optimized for operation in a specific working band, and the AR-coating of each *foXXus* model is optimized for the respective spectrum, detailed specifications are given in Table 3.

Table 3

foXXus_	AR-coating	Optimum* spectrum, nm	Working band, nm (acceptable performance)
0.07-0.22_NA0.38_1030	V-type @ 1040 nm	1020 - 1080	980 - 1100
0.07-0.22_NA0.38_515/1030	W-type @ 520 / 1040 nm	510 – 540 1020 - 1080	500 – 550 980 - 1100
0.07-0.22_NA0.38_343/515	W-type @ 340 / 520 nm	335 – 365 510 – 540	330 – 380 500 – 550
0.01-0.03_NA0.38_1030	V-type @ 1040 nm	1020 - 1080	980 - 1100
0.01-0.03_NA0.38_515/1030	W-type @ 520 / 1040 nm	510 – 540 1020 - 1080	500 – 550 980 - 1100

Spectral transmission graphs are presented in Fig. 7.
These data are based on measurements of reflection of the optical surfaces with AR-coatings.
There may be deviations from the presented graphs in objectives of different production batches.

When operating in the Optimum spectrum, the total losses do not exceed 6%.

Using *foXXus* at a wavelength outside the optimal spectral band will affect the increasing in loss.

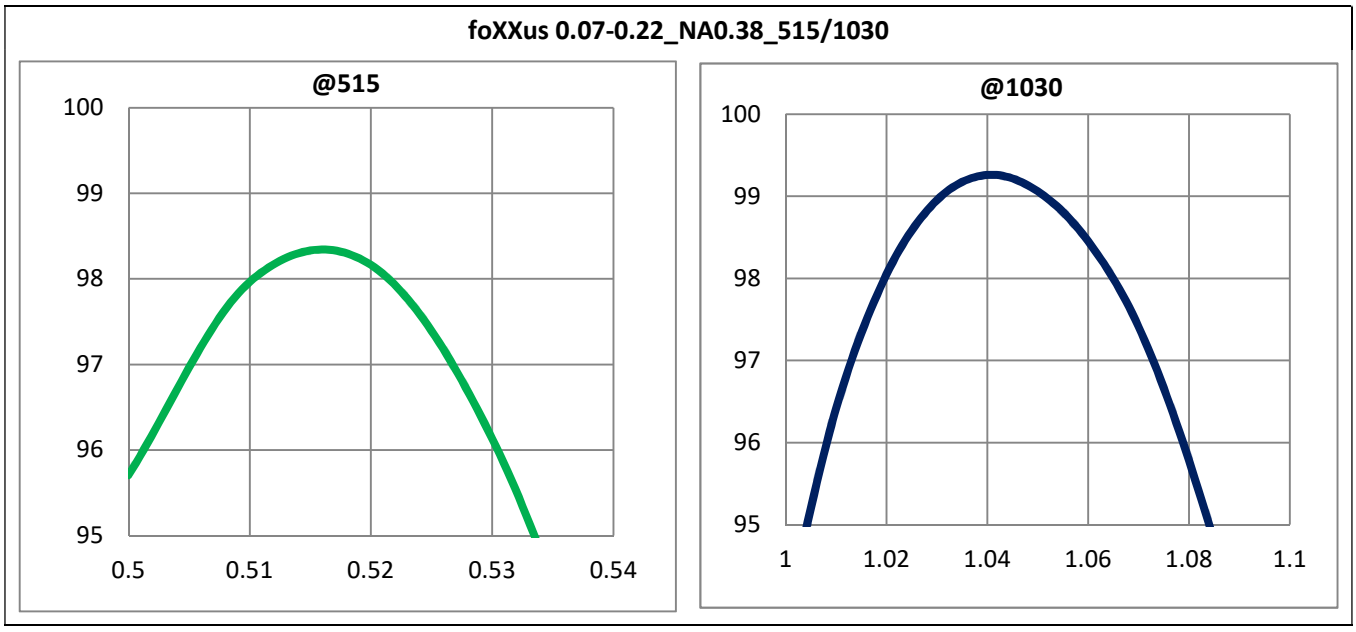


Fig. 7. *foXXus* Spectral transmission, %, versus wavelength, µm, other explanations in text.

Protective Windows D12 are made of optical glass D263 (Schott), thickness 0.17 mm, are optimized for operation in a specific working band, detailed specifications are given in Table 4.

Table 4

Protective Window D12_	**AR-coating**	**Optimum* spectrum, nm**	**Working band, nm** (acceptable performance)
_515/1030	W-type @ 515 and 1030 nm	510 – 535 1020 - 1100	500 – 560 950 - 1150
_1064 (_1030)	V-type @ 1030 nm	1020 - 1100	950 - 1150
_800	V-type @ 800 nm	770 - 900	750 - 950

Spectral transmission graphs are presented in Fig. 8. These data are based on measurements of reflection of the optical surfaces with AR-coatings. There may be deviations from the presented graphs in objectives of different production batches.

When operating in the Optimum spectrum, the total losses do not exceed 2%.

Using Protective Windows D12 at a wavelength outside the optimal spectral band will affect the increasing in loss.

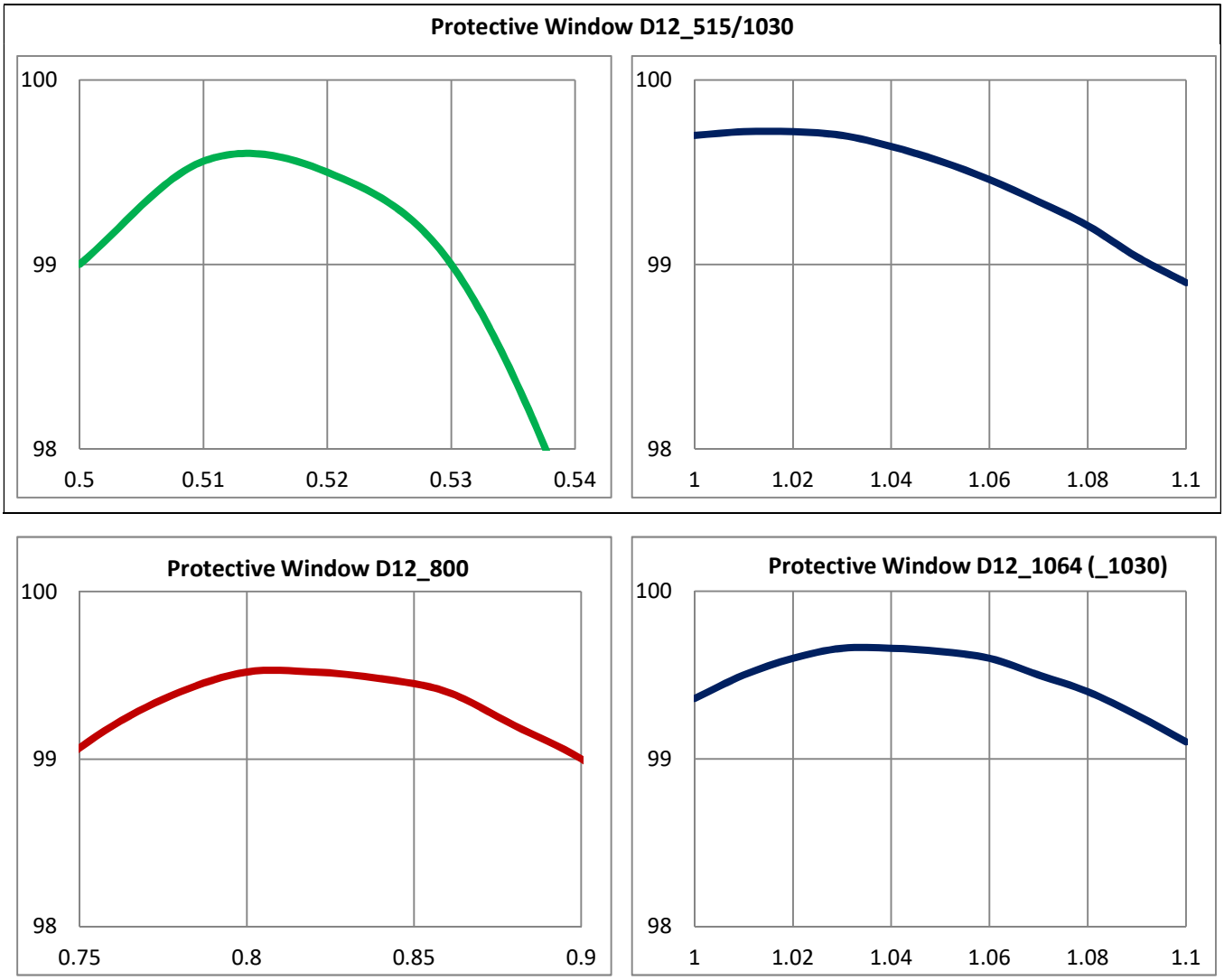


Fig. 8. Spectral transmission of Protective Windows D12 ,
%, versus wavelength, μm, other explanations in text.

7. Recommendations to focusing procedure

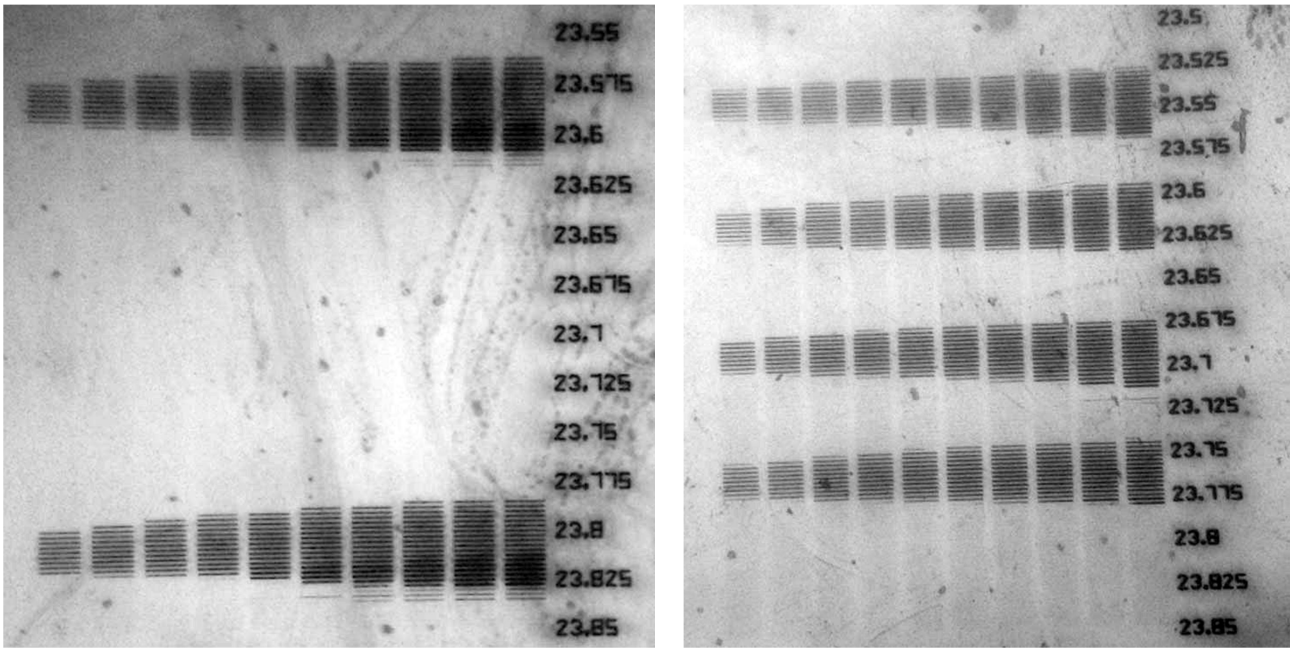
!! Important:

While focusing procedure to move the objective DOWN to a workpiece, i.e. starting from longer distance !!

To avoid focusing of reflected from a workpiece surface light inside the objective lens.

- to do focusing procedure by processing the surface of glass or another material where traces of focused spot are visible,
- step-wise recording of test pattern, for example in form of a short line,
- focusing step 2.5 µm or 5 µm,
- to do focusing procedure using 2 - 3 pulse energy levels, when no essential material damage occurs,
- to use 2 basic configurations: 2-distant foci, 4-foci,
- to analyse the processing results by a microscope.

Examples of focusing procedure for foXXus objective with NA0.38 are presented in below microphotographs by processing of glass surface.



2-distant foci
"Plate" - "2d" Polarization "4"

4-foci
"Plate" - "4" Polarization "2c"

Fig. 9 Settings Examples of focusing procedure with variation of pulse energy.

8. Data for communication with a supplier

By the communication with a supplier for evaluation of the optics performance, it is recommended to present following data measured beforehand:

- Input beam
  - wavelength ,
  - CW or pulse,
  - M^2,
  - $1/e^2$ diameter,
  - power specifications,
  - pulse energy,
  - pulse width,
  - polarization state,
  - orientation of the polarization plane in the case of linearly polarized light,
  - astigmatism and ellipticity,
- Results of focusing procedure according to section 9. “Recommendations to focusing procedure”

  for example, in form of microphotographs by processing surface glass or another material,
- All data relating to the focusing procedure and material processing to be supplied with information about settings of the foXXus and orientation of the polarization plane.

!! Important:

Data with material processing are considered ONLY when the results of focusing procedure are presented