

## User Notes, Ophir Near Field Profiler for C-mount Cameras

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- SP90291**, C-NFP Adapter
- SP90292**, Microscope Objective, 60X
- SP90293**, Microscope Objective, 40X
- SP90294**, Microscope Objective, 20X
- SP90295**, Microscope Objective, 10X

### 1.0 Introduction

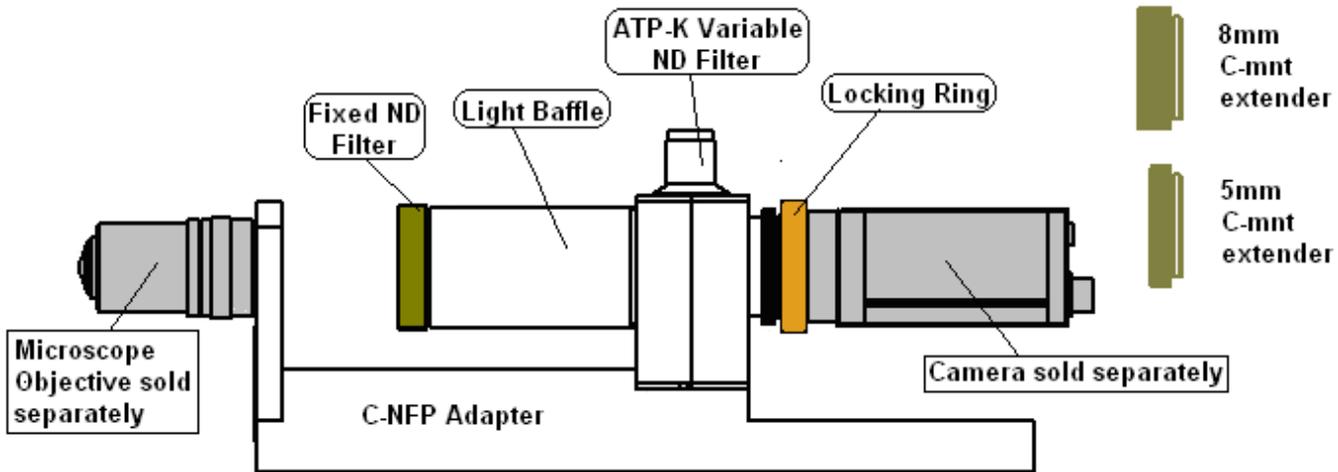
The C-mount Near Field Profiler (NFP) is a microscope attachment for a C-mount camera. It can be used to image and magnify the waist of a focused laser beam. The NFP adapter must be ordered with one or more microscope objectives. The adapter includes ND filters for attenuation of the input laser beam. However it may be necessary to provide additional attenuation before the beam enters the NFP's microscope objective.

It is assumed that the user of this product already possesses a suitable C-mount camera and Spiricon software for capturing and analyzing a laser beam. If not then contact your Ophir-Spiricon sales representative for more information regarding Spiricon's laser beam analysis products.

The magnification of the system will be approximately the power indicated on the microscope objective (MO). The user may substitute any RMS threaded DIN objective and the resulting magnification should be approximately as marked on the objective. The NFP design is based on the DIN microscope standard. However because there are ND filters placed between the objective and the camera the path length to the camera will deviate slightly from the DIN standard. This deviation is the reason that the final magnification of the system may be slightly different than the objective's marking. If a more accurate calibration is required the user must image a calibrated reticle, and using the beam analysis software modify the magnification value as needed.

### 2.0 Assembly

The NFP adapter is supplied w/o a mounted microscope objective or camera. The user must install both the objective and the camera as shown below:

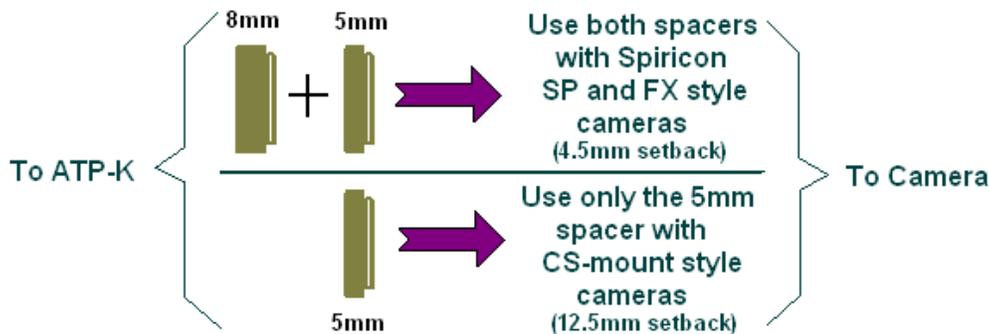


### **C-mount NFP Adapter Assembly**

Shown configured with a C-mount std setback camera

The Light Baffle tube and Fixed ND Filter are threaded into the front of the ATP-K attenuator. The unit is supplied with one bulk absorbing general purpose ND filter. The baffle and filter are C-mount threaded and can be removed, replaced, or added to by substitution with any other appropriately sized and threaded ND filter. Spiricon supplies three (3) ND filters with its CCD camera beam analyzer systems. Additional ND filters are best added at the front of the Light Baffle tube as this is where the input beam's power density will be lowest. ND filters should not be added to the front of the camera.

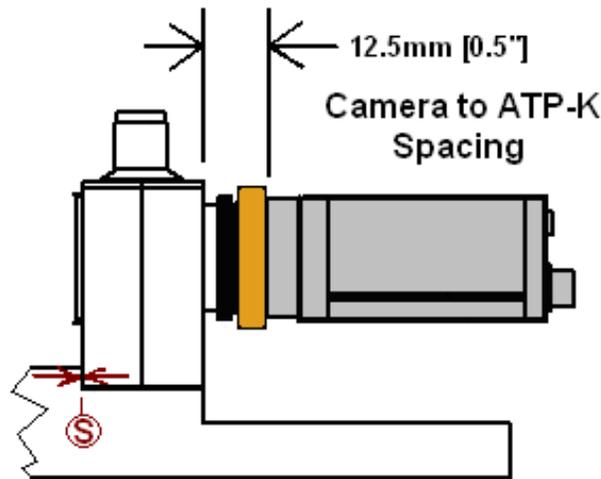
The supplied 5mm and 8mm C-mount spacers are provided for cameras that do not have the standard C-mount (17.5mm) setback from the camera's lens mounting threads to the imager plane. The 5mm spacer is for cameras that have the industry standard CS-mount configuration. For some Spiricon SP (see Table 1) and the older FX series cameras, both the 5mm and 8mm spacer must be used stacked together to achieve a proper setback.



**Note:** The C-NFP Adapter is designed to accommodate most Spiricon laser beam analysis cameras. The cameras are threaded onto the output of the ATP-K variable attenuator. For wider body cameras, the ATP-K must first be removed from the C-NFP base, the camera mounted, and then reinstalled onto the base as a unit. Small cameras can be threaded onto the ATP-K w/o removal.

The camera position and orientation on the ATP-K is secured with the brass locking ring. The distance from the back of the ATP-K to the front of the camera, including the camera spacers if installed, should be adjusted to approximately 12.5mm [0.5"]. This adjustment can only be as good as the threads of the camera and spacers will permit. It does not need to be precise since the final path-length is variable due to the presence of the ND filters.

After installing any required C-mount spacer(s), the camera assembly is threaded onto the back of the ATP-K variable attenuator as shown below. If the ATP-K was removed from the base, reinstall it making sure that the front of the ATP-K is flush with the stepped edge of the base as indicated by the circled S and the arrows shown below.



The total thickness of the ND filters and the ATP-K to camera spacing will determine the final magnification of the system.

The following table lists the compatible Spiricon cameras and indicates which spacers need to be used with each. Many other third- party C-mount cameras can also be used.

Camera	SP907	SP928	SP300	LT665	Gevicam
5mm spacer	Req'd	Req'd	none	none	none
8mm spacer	Req'd <sup>1</sup>	Req'd <sup>1</sup>	none	none	none

**Table 1. Spiricon Compatible Cameras**

The NFP is not compatible with Pyrocam and Xeva camera models.

**Note:** For the legacy SP503 and SP620 cameras both the 5mm and 8mm spacers are needed.

<sup>1</sup> For older SP907 and SP928 cameras sold with the CS-mount housing, the 8mm spacer is not required.

### 3.0 Alignment

The Spiricon MO's employ an A/R coated achromatic lens design. Each MO will have a unique working distance and Numerical Aperture (NA). The user must be aware of the impact that the working distance and the NA has on achieving a proper setup. Below is a table of values for the Spiricon MO's.

Objective	Power	Effective Focal Length, mm	Field of View, mm	Working Distance, mm	NA
SP90292	60X	3.21	0.30	0.15	.85
SP90293	40X	4.35	0.45	0.60	.65
SP90294	20X	8.33	0.90	3.75	.40
SP90295	10X	17.02	1.80	4.40	.25

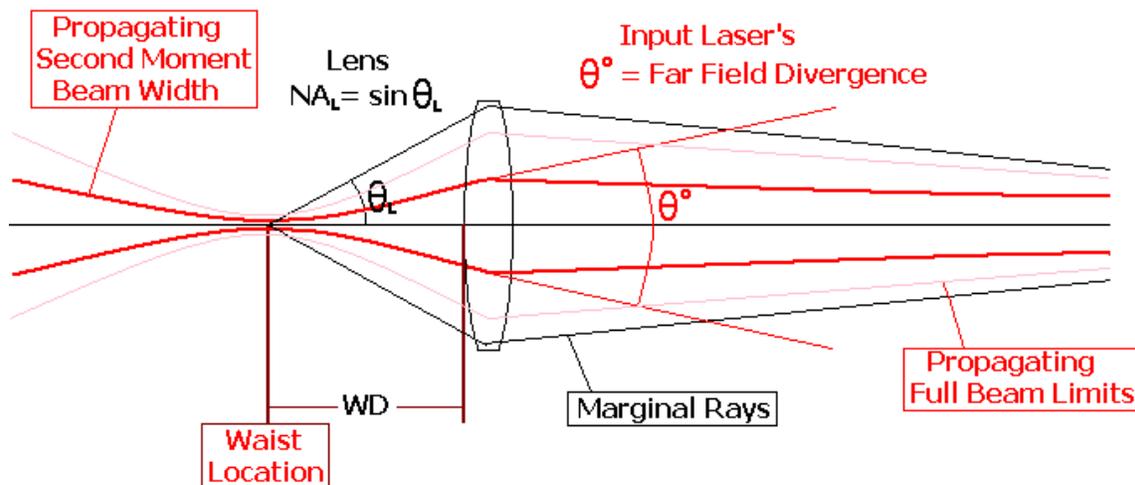
**Table 2. Spiricon Microscope Objective Specifications**

The NA of an MO is calculated as the sine of the angle formed by the marginal ray with the main axis of the system. To image a laser beam all of the beam's rays must fit within the NA of the lens. If the MO's clear aperture clips part of the beam, then the resulting image will likely contain diffraction generated distortions.

The NFP is typically used in two common applications. Each will be addressed below. Note: In each of the following examples the laser/fiber must be centered and properly positioned to achieve a focused image on the camera. Focus in each example is achieved when the resulting image is at a minimum beam width/diameter. In the first example, the beam may be astigmatic and the two waist widths may not reach a minimum at the same location.

### 3.1 Focused Spot Analysis

The NFP can be used to image the size and distribution of a focused laser beam. This focused spot forms a new waist with a corresponding divergence. To image the focused spot the focused beam's waist is placed at the MO's working distance, measured from the front of the lens. The focused beam's half-divergence angle must be no greater than .35X the NA angle of the lens. The focused spot size must be .35X smaller than the MO's field of view. If the above conditions are met the focused spot can be successfully magnified and reimaged on the camera. The figure below illustrates a laser beam fully contained within the NA of the lens with its waist located at the Working Distance of the lens.



The following table lists the laser's maximum full angle divergence vs the lens NA; and the maximum focused spot size for each of the above lenses. Note: All laser measurements are based on standard ISO second moment measurement methods.

Objective	Power	NA	$NA^\circ = \sin^{-1} NA$	$NA^\circ \times .35$	Laser $\Theta^\circ_{max}$	Spot $D_{4\sigma max}$ $\mu m$
SP90292	60X	.85	58	20	40	105
SP90293	40X	.65	40	14	28	157
SP90294	20X	.40	23	8	16	315
SP90295	10X	.25	14	5	10	630

**Table 3. Laser Beam Divergence and Spot Size Maximums vs Objective**

**Example:** My laser is focused to a spot size of ~20um with a full divergence angle of 35°. What is the best lens to use to image this focused spot?

**Answer:** The small 20um size satisfies the maximum spot size for all of the above MO's. However only the SP90292 (60X) can accommodate the 35° beam divergence angle. 20um X 60 will yield a 1200um image on the camera's imager. This requires a camera imager at least 2.4mm on a side. This will easily fit on all of Spiricon's supplied cameras.

### 3.2 Fiber Optic Core Analysis

The NFP can be used to measure the Mode Field Diameter (MFD) of single mode optical fiber. Optical fibers are often specified by both MFD and NA. However the NA of an optical fiber is defined differently than the NA of the MO. In fact different fiber manufactures often choose slightly different methods for measuring a fiber's NA. Knowledge of a fiber's MFD is useful in the matching and splicing of one optical fiber to another. A mismatched MFD can cause splice losses.

To measure a single-mode fiber's MFD the cleaved end of the fiber is placed at the working distance of the lens and magnified by the NFP onto the camera. Measuring the properly scaled second moment beam width is equal to the fibers MFD. In order to make an accurate measurement, the NA of the fiber must fall well within the NA of the MO. The industry standard NA criteria for fiber optic cable is measured using a 5% of peak clip level. However some cable makers use other clip levels, some as low as 1%. The table below will assume the 5% clip level since fibers measured at <5% will easily fall within the 5% limits.

Objective	Power	NA	$NA^\circ = \sin^{-1} NA$	$NA^\circ \times .5$	Fiber $NA^\circ_{max}$ @ 5% of Peak	Fiber 5% $NA_{max}$
SP90292	60X	.85	58	29	29	.48
SP90293	40X	.65	40	20	20	.34
SP90294	20X	.40	23	11.5	11.5	.20
SP90295	10X	.25	14	7	7	.12

**Table 4. Fiber Optic Cable NA vs Objective**

**Example:** My single mode fiber has a published NA of .19 based on a 5% of peak criteria and a core diameter of  $\sim 10\mu\text{m}$ . What MO should be used to measure the fiber's MFD.

**Answer:** The .19 criteria is below the  $\text{NA}_{\text{max}}$  for the top 3 objectives listed above. It's very close to the 20X, so to be conservative choose the 40X objective. The 40X magnification will produce a beam image in the 400um range which can be resolved and measured with typical Spiricon supplied cameras.

**Note:** As can be seen in the above lens data, the working distances for MO's are short and very close to the lens. Changing the fixed ND filters and making adjustments to the variable ND filter can slightly alter the focus. This necessitates a very stable setup with some type of fine focus adjustment for positioning either the NFP or the input source. This requirement has been left up to the user to adapt to their particular application.

## 4.0 Damage Limits

The NFP is primarily designed for imaging low power laser beams under 100mW. At this input power level none of the optical elements should be stressed. As the power level increases, the first risk becomes heating of the bulk absorbing ND filters. If they see power levels  $> 5 \text{ W/cm}^2$  thermal lensing will likely occur. The  $5 \text{ W/cm}^2$  value is not precise. It's a function of wavelength and the degree of absorption at that wavelength. Use it as a rule of thumb, but check for beam distortion as the power density nears this region.

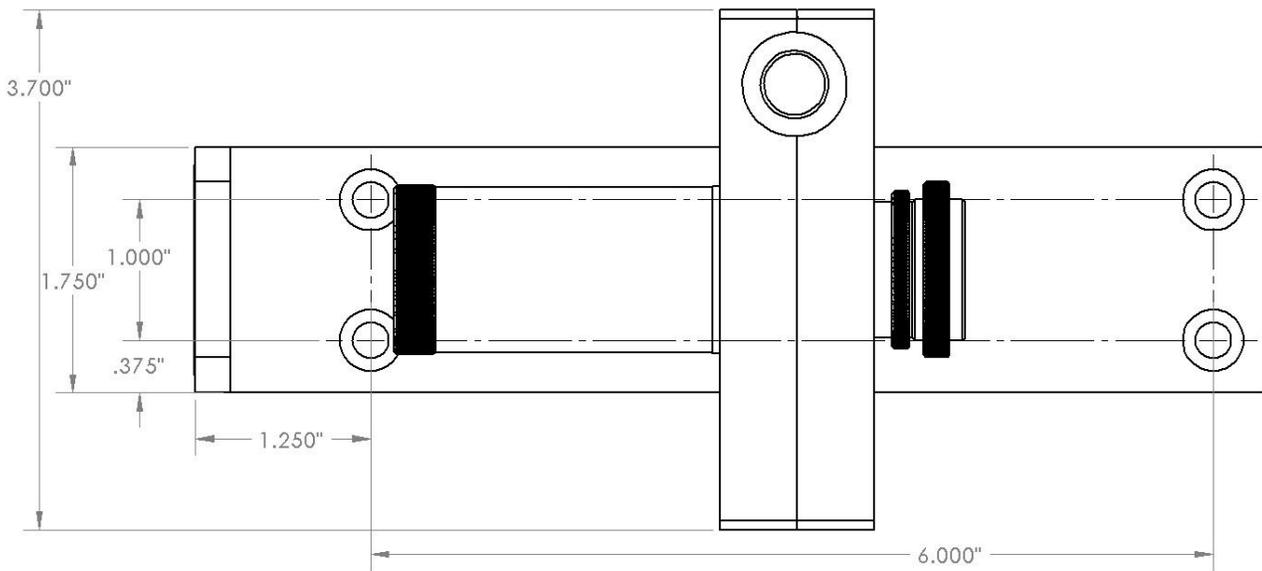
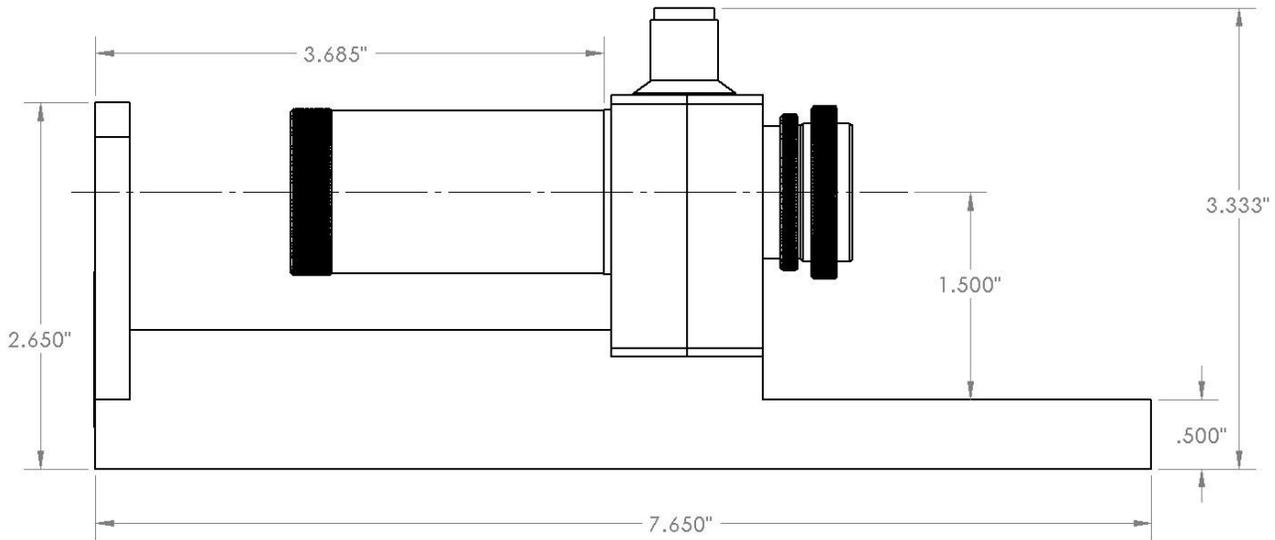
Most bulk absorbing ND filters will damage at power levels approaching  $50 \text{ W/cm}^2$  or  $1 \text{ J/cm}^2$  for a 10ns pulse. These limits are also not precise and change with wavelength and the absorption properties of the various ND filter glasses.

To insure long life and best accuracy the user is advised to employ as much upfront beam attenuation as necessary to keep clear of the NFP's damage thresholds.

**The following additional components can be purchased separately:**

Description	Part Number
ATP-K Variable Attenuator	PH00128
ND1 Filter (red housing)	SPZ08234
ND2 Filter (blk housing)	SPZ08235
ND3 Filter (grn housing)	SPZ08253
5mm C-mount spacer	SP90079
8mm C-mount spacer	SP90080

Dimensions w/o Microscope Objective and Camera



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