Depth of Focus for Standard Probes

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The depth of focus for metrology applications using the OptiGauge[TM], is defined as the range of distances between the sample and the optical probe, where the amount of light reflected by the sample and coupled back into the OptiGauge is sufficient for reliable measurement purposes.

In the field of Laser Physics, the theoretical depth of focus for a given optical system is defined as twice the Rayleigh Range (RR),

$$RR = \frac{\pi\,\omega_0^2}{\lambda} \approx \frac{\pi}{\lambda} \cdot \left(\frac{2\lambda}{\pi NA}\right)^2 = \frac{4\lambda}{\pi NA^2}$$

where ω_0 is the beam waist radius, and NA is the numerical aperture of the probe. The imaging space NA of the probe can be modeled in Zemax, by setting the object space NA to the full NA of the single-mode fiber at $1/e^2$ of optical power, fNA_{obj}=0.19.

In practice, the Rayleigh Range is a poor measure of the working range for the probe, due to high sensitivity of the OptiGauge[TM]. In addition, DOF varies depending on the material reflection properties: it is larger for stronger reflecting interfaces (e.g. glass-air) and smaller for weak reflecting interfaces (e.g. plastic coating on top of a plastic substrate).

For the purposes of this white paper, we have measured the DOF for the air-glass interface of 2 probes, 13000-20 and 13000-58. The measured DOF was the range where the signal level in the OptiGuage remained above 60%. We found that the measured DOF is 50 times larger than the calculated RR. We assumed that this rule applied to other probes as well, i.e. the numbers in the pDOF column are calculated by multiplying column RR by 50. Given that these numbers were obtained for the air-glass interface, the numbers in pDOF column represent the best-case scenario.

Part#	WD[†], mm	fNA, rad	RR, mm	pDOF, mm	WR, ±mm
13000-10	50	0.041	1.002	50	8
13000-20	20	0.087	0.220	11	5
13000-58	20	0.204	0.040	2	1
13000-72	145	0.049	0.696	35	15
13000-75	90	0.020	4.008	200	8
13000-76	13.5	0.189	0.047	2	1

[†]WD – Working distance, fNA – image space full NA at $1/e^2$, RR – Rayleigh Range, pDOF – practical depth of focus, WR – working range (half of pDOF, or limited by the range of OptiGauge)

Due to the approximate nature of these calculations, the data for the last column is rounded down. In addition, the data is truncated if it is above the OptiGauge measurement limit of ±8 mm (except for 13000-72 probe, designed for the larger-range OptiGauge MLS).

References:
http://en.wikipedia.org/wiki/Rayleigh_length