Instruction Manual: Confocal Laser Methods for Quantitative Evaluation of Dioptric Power Characteristics of New-Technology Intraocular Lens Implants

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Instruction Manual

The principle Confocal Laser Method (CLM) tool design developed and implemented for high-accuracy, repeatable, objective, and robust evaluation of dioptric power characteristics of currently used and new-technology intraocular lens (NTIOL) implants is illustrated in Fig. 1 [1-8]. The CLM tool design is based on a simple apertureless fiber-optic laser confocal arrangement, which includes a critical single-mode fiber component that serves simultaneously as a point light source used for formation and precise focusing of a collimated Gaussian laser beam, as well as a confocal point receiver that is highly sensitive to spatial displacement of the focused back-reflected laser emission. Moreover, the use of a monochromatic laser emission with Gaussian beam intensity distribution and relatively small beam diameter provides near-to-the-theoretical paraxial conditions for collimating and focusing the testing laser beam while various aberration effects have a negligible influence on the CLM measurement accuracy. Thus, because of these advanced features, the fiber-optic CLM design provides a precise spatial location of the IOL focal point when the total back-reflectance mirror is axially scanning and therefore, a high accuracy in measuring the focal length and evaluating the dioptric power of the tested IOL implants can be achieved.

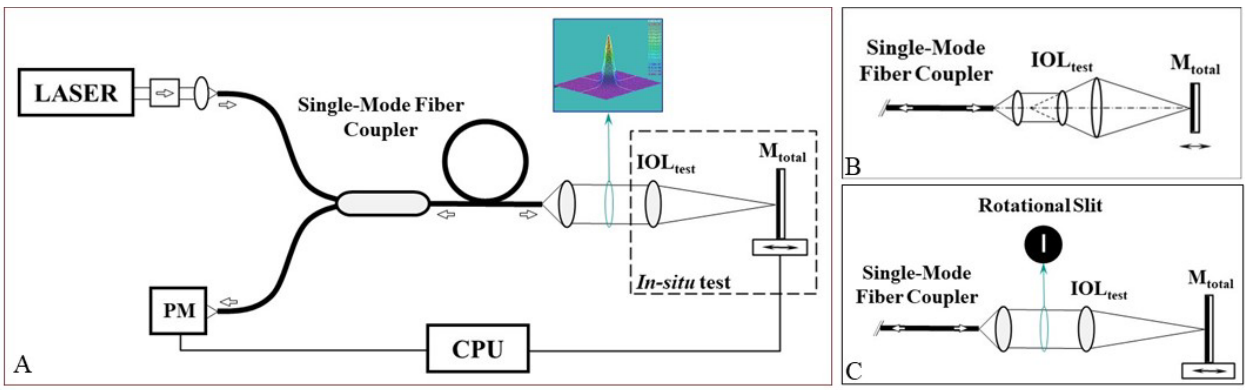

Fig. 1: A principle CLM design for IOL dioptric power testing (A); and additional CLM setups for negative (B) and toric (C) NTIOL dioptric power testing.

The CLM tool designs are applicable and have been implemented for dioptric power evaluation of various NTIOLs including both positive and negative monofocal IOLs, toric, multifocal, accommodative, and extended depth of focus (EDF) IOLs. The major results of these CLM tool applications are included in peer-reviewed studies and issued patents [1-8]. The CLM tools involve some additional specialized setups that can be applied as test tools for dioptric power evaluation of specific IOL designs, such as both positive and negative monofocal IOLs (Fig. 2b, [1,3,5], or toric IOLs with the introduced new advanced sensing technique based on a rotational slit approach used for detecting and evaluating of both spherical equivalent (SE) and cylinder (C) powers (Fig. 2c, [2,4]). Moreover, the CLM tools provide the standard options for IOL dioptric power evaluation in both dry air and *in-situ* simulation conditions (Fig. 1a).

The CLM test procedure for evaluating dioptric power characteristics of currently used and new-technology intraocular lens (NTIOL) implants includes the following key steps:

- Employ the CLM test methodologies and principal CLM setups presented in Fig. 1 and described in Ref. [1-8] including specifications of the key RST components to assemble the CLM tool designs.
- Perform precise alignment of the optical CLM setup to maximize the laser-to-fiber coupling efficiency, to provide a parallel collimated Gaussian laser beam, and to align IOL sample and back-reflectance mirror at normal incidence towards the collimated laser beam.
- Locate the back focal point of the IOL sample by axial scanning of the back-reflectance mirror and maximizing the detected backscattered laser power.
- Determine the standardly specified and required IOL back focal length (F_{BFL}) of the test IOL sample by measuring the distance between the located back focal point and the IOL's back vertex using precise translational micrometric stages or the located half-focal point [4]. The back focal length (F_{BFL}) can be determined both in air ($F_{BFL\text{-}air}$) and *in-situ* simulation conditions ($F_{BFL\text{-}In}$).
- Use of the measured back focal length F_{BFL} to calculate the effective focal length F_{eff} of the IOL employing the following equation [1-3]:

$$F_{eff} = F_{BFL}/[1 - t_s\,(n_{IOL} - n_{med})/n_{IOL}\,R_1] \qquad (1)$$

  where t_s is the IOL thickness; R_1 is the front surface radius of curvature; n_{IOL} and n_{med} are the refractive indexes of the IOL and the surrounding medium (in air $n_{med} = 1$), respectively. The effective focal length F_{eff} can be calculated both in air ($F_{eff\text{-}air}$) and *in-situ* simulation conditions ($F_{eff\text{-}In}$). In case of thin ($t_s \approx 0$) or planoconvex ($R_1 \approx \propto$) lenses, Equation (1) is reduced to the simple dependence: $F_{eff} = F_{BFL}$ [1-3].

- Calculate the dioptric power of the test IOL sample in air ($D_{IOL\text{-}air}$) or *in-situ* simulation conditions ($D_{IOL\text{-}in}$) using the equations [1-3, 5]:

$$D_{IOL\text{-}air} = 1/F_{eff\text{-}air}\,,\quad D_{IOL\text{-}in} = n_{med}/F_{eff\text{-}in} \qquad (2)$$

- In case of toric NTIOLs applied to correct the corneal refractive astigmatism, employ the CLM tool to measure the back focal length F_{BFL} and to calculate the spherical dioptric power S, which is identical to the effective focal length F_{eff} determined by Equation (1) [2,4]. Use the rotational slit aperture setup of the CLM tool (Fig. 1c) to detect the anterior cylinder axis of toric IOLs and determine the cylinder power C. Calculate the spherical equivalent power (SE) using the following equation [2,4]:

$$SE = S + 0.5\,C \qquad (3)$$

- Perform the CLM tool based quantitative studies for evaluating dioptric power characteristics of various NTIOL designs in compliance with the IOL standard requirements as well as the limiting test conditions and corrections related to the environmental temperature [6], multiwavelength dispersion [7] and laser beam width effects [8].

Publications:

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