Carmel Laser

White Paper

Revision 1.0
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Overview

The Carmel CFL-05RFF0 is a high power, 780 nm, fiber based femtosecond laser. Its ultra compact laser head is over 100 times smaller than many Ti:Sapphire lasers with a similar output power level. It is a turnkey, rugged industrial laser system with a portable design and excellent system stability. Push button startup and no maintenance makes our fiber lasers easy to use and hassle free. The CFL series offers user-friendly front panel control knobs for flexible system adjustment. The pulse width is less than 100 fs with a negligible pedestal.

The repetition rate can be specified from 10 to 50 MHz with a polarization-maintaining (PM) output and excellent beam quality, with an $M^2 < 1.2$. Excellent pulse-to-pulse stability (<1% rms) combined with a clean spectrum and clean pulses over a wide operating temperature range (17-32 ^{o}C) provides superior results for both microscopy imaging and tissue ablation in biomedical applications. An RF synchronization output is provided as a trigger signal.

For multiphoton spectroscopy applications, the Carmel offers ideal performance to optimally image tissue with less scatter and lowered risk of tissue damage. The compact size and fiber delivery simplifies implementation by eliminating costly redesign of delivery optics and by easily integrating within existing microscopes.

Calmar’s CFL operation is based upon the company’s proprietary passive mode-locking technology, which ensures reliable startup and stable long term performance. Carmel high power, fiber based femtosecond lasers enable end users to focus on the job at hand, and not the laser tool being used.

Features

- Field proven product reliability
- Ultra compact laser head
- Easy to use
- Wavelength 780 nm
- Pulse energy > 10 nJ

- Pulse widths < 100 fs with negligible pulse pedestal
- RF synchronization output
- High repetition rate of 50 MHz
- Air cooled – no chiller required
- Low power consumption
- Excellent beam pointing and pulse energy stability
- Fiber Beam Delivery for simplified optical path and reduced optical dispersion.

Background

Since 1996, Calmar has been a technological leader in the design and manufacture of all-fiber ultrafast lasers the ophthalmology, microelectronics, solar, telecom, and scientific research markets. Fiber lasers offer the advantages of long life semiconductor diode combined with the efficiency, reliability, performance and low cost of optical fiber amplification. These key advantages have created a significant momentum to adopt fiber laser technology (versus legacy laser technologies) for a wide range of research and industrial applications.

Calmar's femtosecond laser sources are passively mode-locked fiber lasers. Passive mode-locking makes these lasers easier to operate than actively mode-locked lasers, as no external RF clock signal is required, and little or no warm-up time is needed. Temperature control is also less of an issue with passive mode-locked lasers.

Calmar's passively-mode-locked lasers produce pulses as narrow as 80 fs wide. Repetition rates are fixed in the range 10 - 100 MHz. The peak output power of a femtosecond laser is, of course, high due to the short pulse durations, and peak powers up to 10 KW can be achieved using an integrated EDFA. Figure 1 shows a simplified schematic of a passively mode-locked fiber laser.

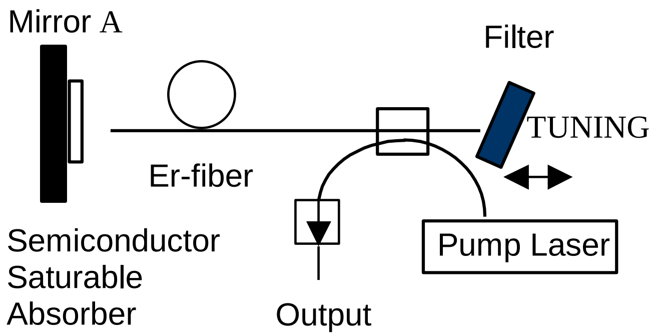


Figure 1 – Schematic of Passive Mode-locked Fiber Laser

Since Calmar’s fiber lasers are manufactured from discrete components, dispersive and non-linear effects can be carefully controlled. Pulse shape is transform-limited, and the pedestal is typically 20dB lower than the signal.

Calmar’s lasers are recognized for their stability, as demonstrated by their low timing jitter and low amplitude noise, thereby ensuring that the quality of the laser output meets even the most stringent test requirements.

Technical Specifications

The following table provides specifications for the Carmel Femtosecond Fiber laser.

Model Number	CFL-05RFF0
OPTICAL	
Wavelength (nm, FWHM)	780 ± 5
Average Power (mW)	> 500
Pulse Width[2] (fs)	< 100 (90 typical)
Pulse Energy (nJ)	> 10
Peak Power (kW)	> 100
Beam Quality	$M^2 < 1.2$
Beam Diameter (mm, $1/e^2$)	0.7 ± 10%
Beam Roundness (%)	> 90
Spectral Width (nm)	~ 10 (typical)
Nominal Pulse Repetition Rate[1] (MHz)	50
Polarization Ratio (dB)	> 25
Pulse Energy Stability (%RMS, 8 hours)	<1
ELECTRICAL	
Supply Voltage (VAC)	85 ~ 264 auto ranging
Supply Frequency (Hz)	47 ~ 63 auto ranging
Power (VA)	200
RF Synchronization Output	Included
MECHANICAL	
Warm up time	10 minutes (typical)
Operating Temperature (°C)	17 - 32
Storage Temperature (°C)	0 ~ 50
Length of fiber between controller and head (cm)	80
Laser Head Dimensions (cm)	3.0 (w) x 13.0 (d) x 9.0 (h)
Laser Head Weight (kg)	0.1
Laser Controller Dimensions (cm)	48 (w) x 50 (d) x 18 (h)
Laser Controller Weight (kg)	12
Cooling	Air-Cooled

1 Other nominal repetition rate can be factory-configured, may affect other specifications

2 A sech2 pulse shape (convolution factor of 0.65) is used to determine the pulse width from the second harmonic autocorrelation trace.

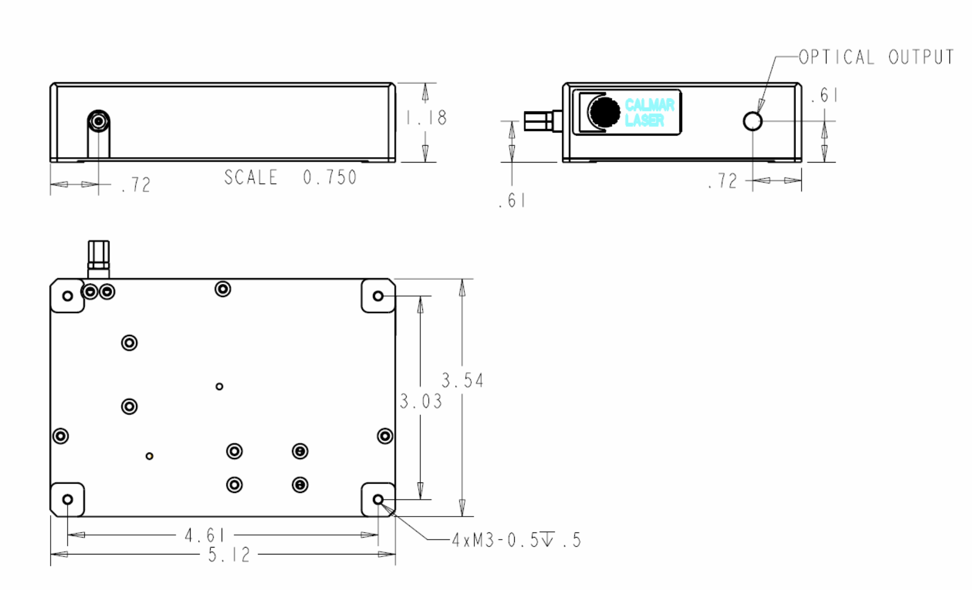
Due to continuous improvement, all product specifications are subject to change without prior notice.

Table 1 – Specifications for Femtosecond Fiber Lasers

Mechanical Dimensions

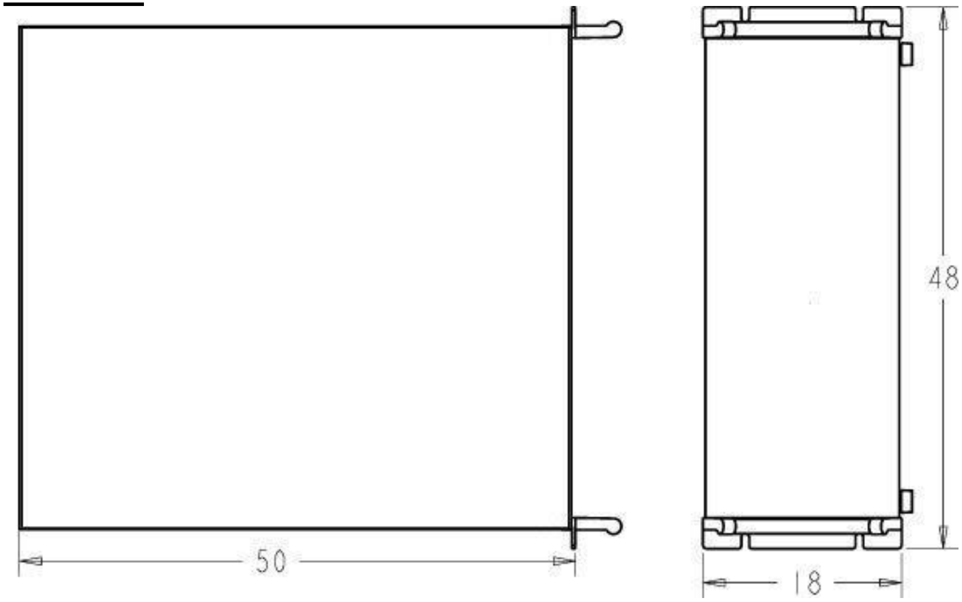
The Laser Head and Controller are connected by a flexible shielded fiber with length of 80 cm.

Laser Head



Scale in inches

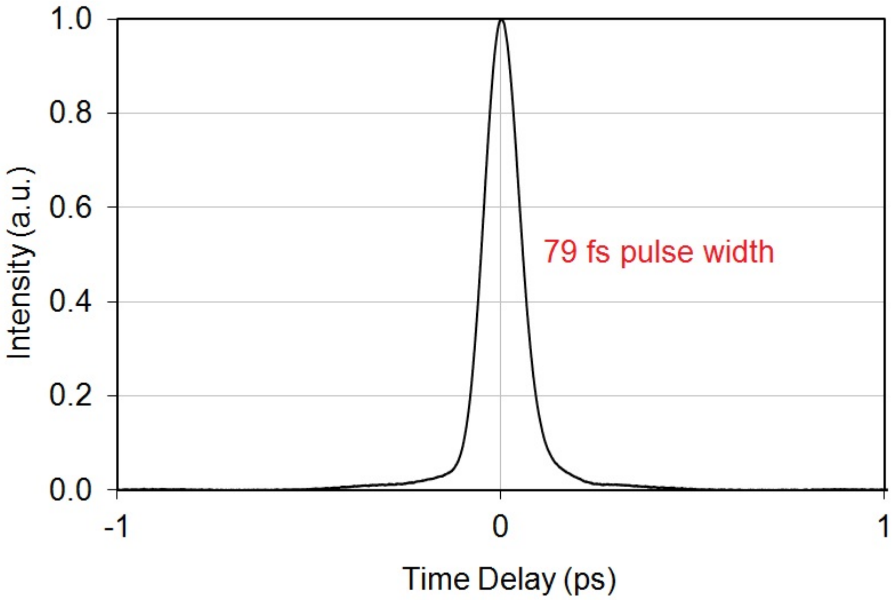
Controller



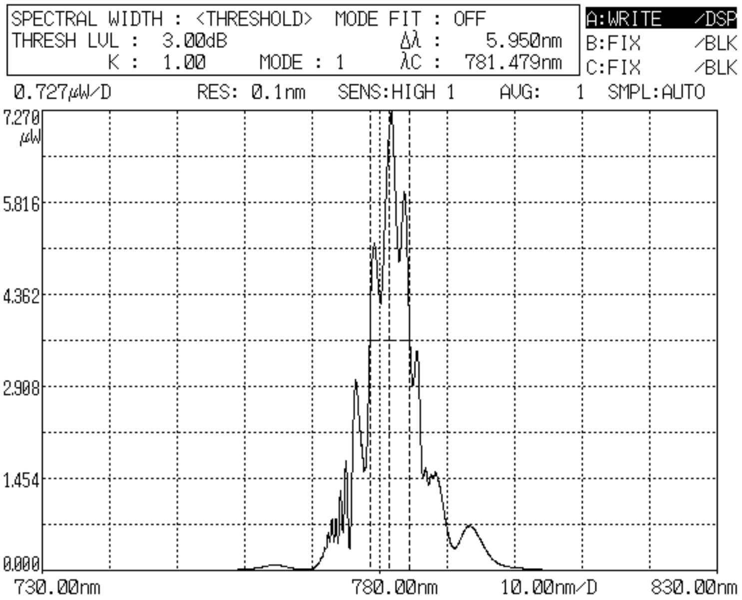
Scale in centimeters

Performance

The following test results give an indication of the optical performance of Calmar's Femtosecond Fiber Laser.



Typical pulse shape => Gaussian, 79 fs, no pedestal



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SPECTRAL WIDTH : <THRESHOLD>  MODE FIT : OFF          A:WRITE   /DSP
THRESH LVL :  3.00dB               Δλ :     5.950nm   B:FIX     /BLK
         K :  1.00     MODE : 1    λC :   781.479nm   C:FIX     /BLK
 0.727µW/D        RES: 0.1nm   SENS:HIGH 1    AVG:    1  SMPL:AUTO
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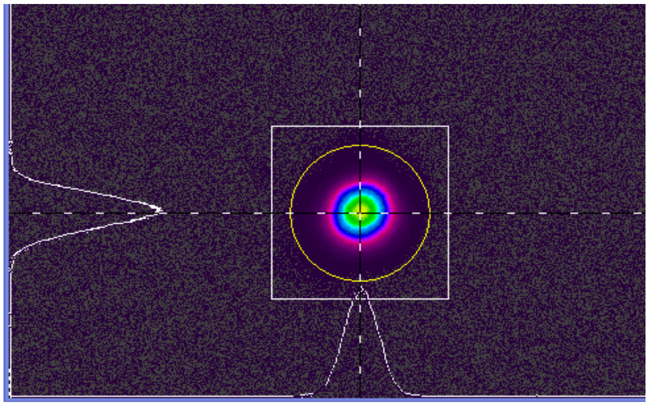
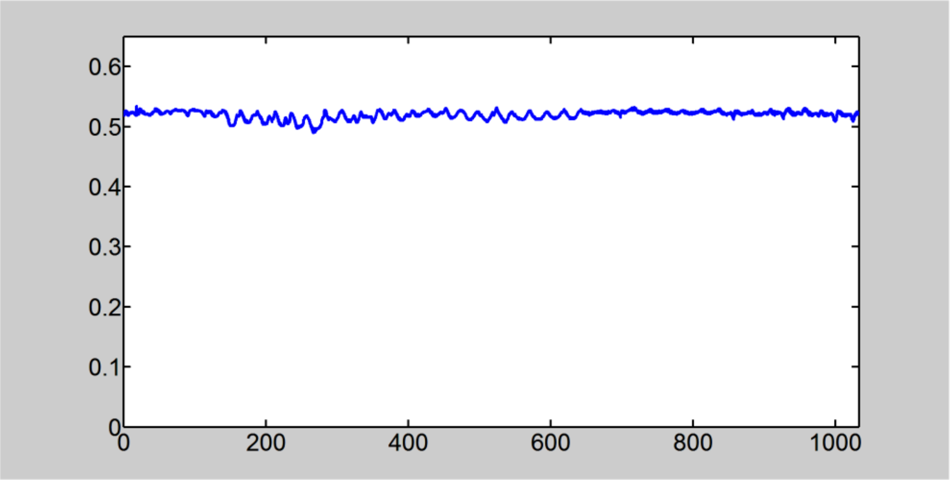
Beam Quality



M^2 X = 1.040;
M^2 Y = 1.039;
Astigmatism = 0.03.

Power Stability over 1000 hours



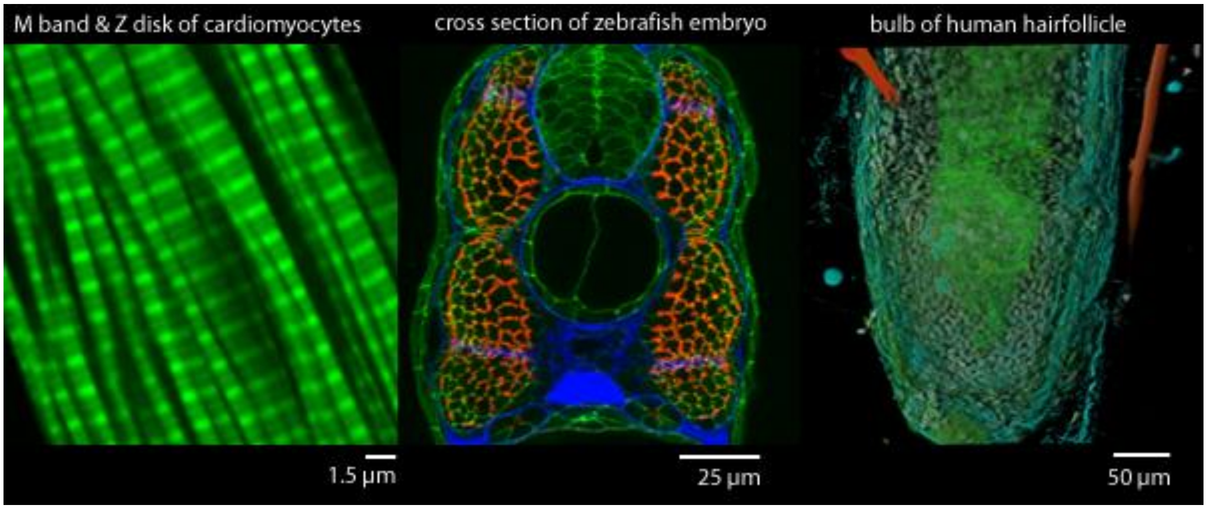
Applications

The Carmel femtosecond laser has many applications:

- Multiphoton microscopy
- Biophotonics
- Materials characterization
- Optical metrology
- Terahertz radiation

Multi-Photon Microscopy

The short pulse and high beam quality of the Carmel laser allow it to be focused tightly with high beam intensity for multi-photon microscopy. In this application, fluorescence only occurs when the laser intensity is sufficiently high to create absorption of multiple photons at one time, usually only at the focal point of a beam. By scanning this focus in three dimensions and collecting the fluorescent light, a three dimensional beam image can be created as shown below.

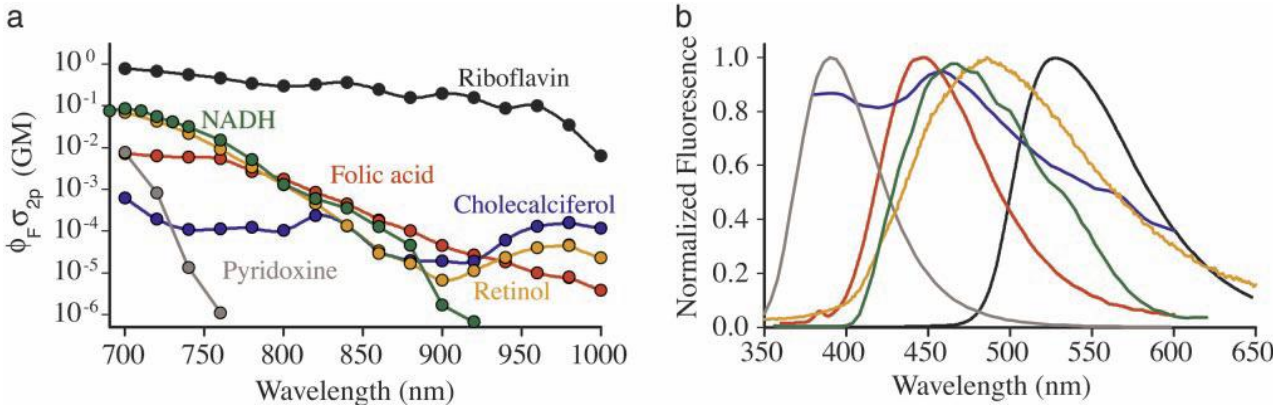


Because absorption only occurs at the highest intensity, it’s possible to have spatial resolution smaller than a wavelength of light with use of high Numerical Aperture focusing lenses. Furthermore, because scattered input light is too low an intensity to create added florescence, it does not cause interference or reduction of resolution on deeper scans. As such the depth of the three dimensional image is only limited by the available source power and emission detection level. In practice, powers above a few 10s of mW can cause damage, even in a scanning application, and image depth is often limited to 100s of µm from the surface. However, optical losses in the microscope and scanning system, especially if they are not optimized for the infrared, can cause a requirement for 100s of mW of source laser power to reach the damage threshold limits for maximum depth.

Compared to Confocal Microscope Imaging, Multi-photon Imaging relies on a nonlinear absorption process which offers the following advantages:

- Inherent z-axis (depth) resolution
- Higher resolution- close or even beyond the diffraction limit (multiphoton excitation)
- Fast – capable of following physiological processes
- Higher sensitivity - no confocal aperture that blocks up to 99% of emission
- Increased penetration depth due to reduced interference from scattered light.
- Reduced photodamage/ photobleaching
- In-vivo imaging with reduced photodamage to sample.
- Possibility of fluorescent lifetime imaging
- A Confocal Microscope system is complex and for UV excitation needs fused silica optics

Of note, new dyes and florophores have become readily available with improved absorption in the 780 nm range.



References for Multi-Photon Imaging

Warren R. Zipfel, Rebecca M. Williams, Richard Christie, Alexander Yu Nikitin, Bradley T. Hyman,and Watt W. Webb, “Live tissue intrinsic emission microscopy using multiphoton-excited native fluorescence and second harmonic generation”, PNAS

Fritjof Helmchen & Winfried Denk, “Deep Tissue two-photon microscopy”, Nature Methods, Vol. 2, No. 12, Dec. 2005, p. 932

Related Web Links:

Live tissue intrinsic emission microscopy using multiphoton-excited native fluorescence and second harmonic generation, Warren R. Zipfel, Rebecca M. Williams, Richard Christie, Alexander Yu Nikitin, Bradley T. Hyman,and Watt W. Webb*

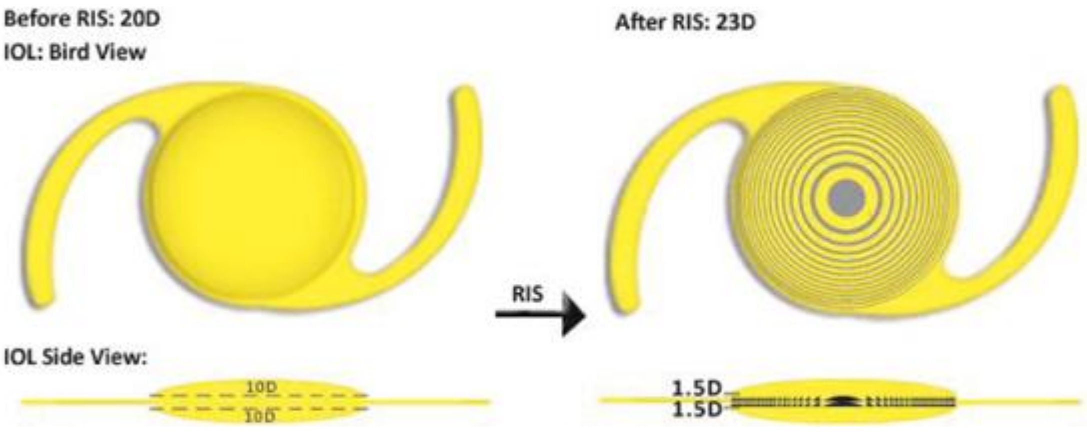
Small animal in vivo imaging market to reach $1.55B in 2017, says report

Microscopy technique heightens understanding of brain cell death during stroke

Two-photon excited fluorescence imaging is useful for identifying ovarian tumors in mice

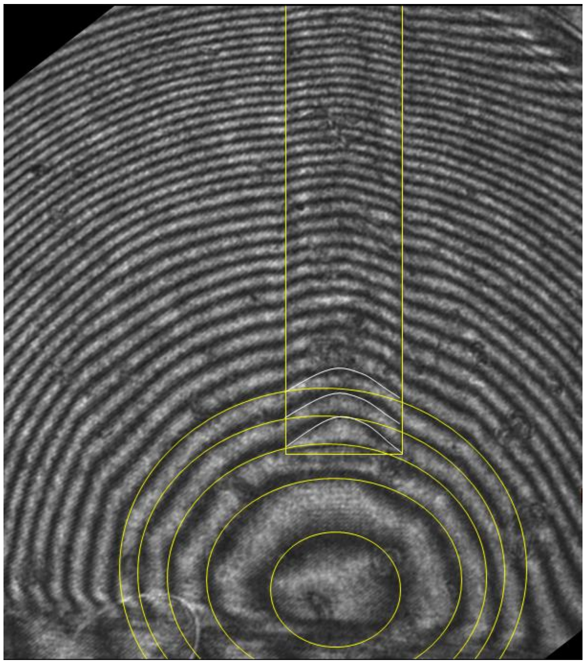
Intra-Tissue Refractive Index Shaping (IRIS)

Another femtosecond laser application for vision correction is Gradient Index Microlenses generated by scanning femtosecond laser pulses inside the cornea for in situ creation of customized Intraocular Lenses (IOLs). This technique allows correction for errors in cataract surgeries that are can occasionally have more than 1 Diopter of residual refractive error.



Using femtosecond laser pulses to target a predetermined 3-D space can typically cause a 1% change in refractive index. Using a 500-mW laser, an inscribing speed of 120 mm/sec and higher could be achieved with 0.8-µm resolution of the inscribing pattern. [1]

Ohthalmic hydrogel polymers are micro-machined with near-infrared femtosecond laser pulses. Refractive index changes up to +0.05 have been obtained, and lateral gradient index refractive structures are written into the flat polymers. By measuring the transmitted wavefront of the micromachined polymer, astigmatism as high as 0.8 diopters can be induced in the micromachined region. [2]



Interferogram of polymer sample with cylindrical lens written in dotted rectangular area. The solid curve represent the trend of fringe of the bulk sample. The additional curve in rectangular area shows additional parabolic phase added to the bulk sample fringes. [2]

References for IRIS:

1. “Laser advances custom intraocular lenses in situ”, Ophthalmology Times, Feb 15, 2011.
2. “Lateral gradient index microlenses written in ophthalmic hydrogel polymers by femtosecond laser micromachining”, Optical Materials Express, Vol. 1, Issue 8, pp. 1416-1424 (2011)

For more information on our Compact Fiber Laser, Picosecond Fiber Laser series, Femtosecond Fiber Laser series, or any other Calmar products, please contact us.

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