Contribution ID: **7** Type: **not specified**

Aberration correction with adaptive optics for lowering the threshold energy for femtosecond laser induced optical breakdown in a water based eye model

Wednesday, 4 September 2013 12:20 (20 minutes)

Abstract content
(Max 300 words)
Special Chars

In vision science, individual eye aberrations often compromise the quality of images of or stimuli to the retina. Here, adaptive optics is an established method for aberration correction. In femtosecond laser ophthalmic microsurgery, optical aberrations of the eye distort the irradiance profile at the laser focus which reduces the precision. Furthermore, the distorted focus increases the required laser pulse energy for the surgery process of laser-induced optical breakdown which increases the risk of collateral damage. For this reason, vitreo-retinal surgery in the posterior part of the eye has so far been considered impossible. The combination of adaptive optics for vision science with a femtosecond laser for ophthalmic surgery could overcome the obstacle of eye aberrations and therefore enable vitreo-retinal laser microsurgery. In this study we used water for modeling eye tissue during optical breakdown. Optical breakdown threshold was determined in single pulse plasma transmission loss measurements. We show that the threshold energy can be considerably reduced when using adaptive optics for aberration correction. For initial aberrations with a root-mean-square wave front error of only one third of the wavelength an adaptive optics aberration correction to the diffraction limit enables a reduction in threshold energy by a factor of three. At twice the threshold the transmitted pulse energy is reduced by seventeen percent. The reduction in both applied and transmitted pulse energy when correcting for aberrations could be transferred from the model eye to ophthalmic applications. With the present work we are confident that ophthalmic surgery could benefit from an aberration correction with adaptive optics, especially with regard to retinal safety. A lowered threshold energy for laser induced optical breakdown poses an important step towards femtosecond laser vitreo-retinal surgery.

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Session Classification: Session VI: Vision

Track Classification: Oral Presentation