Ophthalmic Scatterometry

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INTRODUCTION

Most medical pathologies cause optical properties variations of the affected tissue. Most of current triage methods are based on imaging (e.g. ophthalmoscope, fundus camera, slit lamp, OCT), namely creation of a visual representation of the affected tissue. A scatterometer measures optical properties without creating an image. Nevertheless, a scatterometer measures a distribution of optical properties that enables deduction of a myriad of parameters otherwise undetectable.

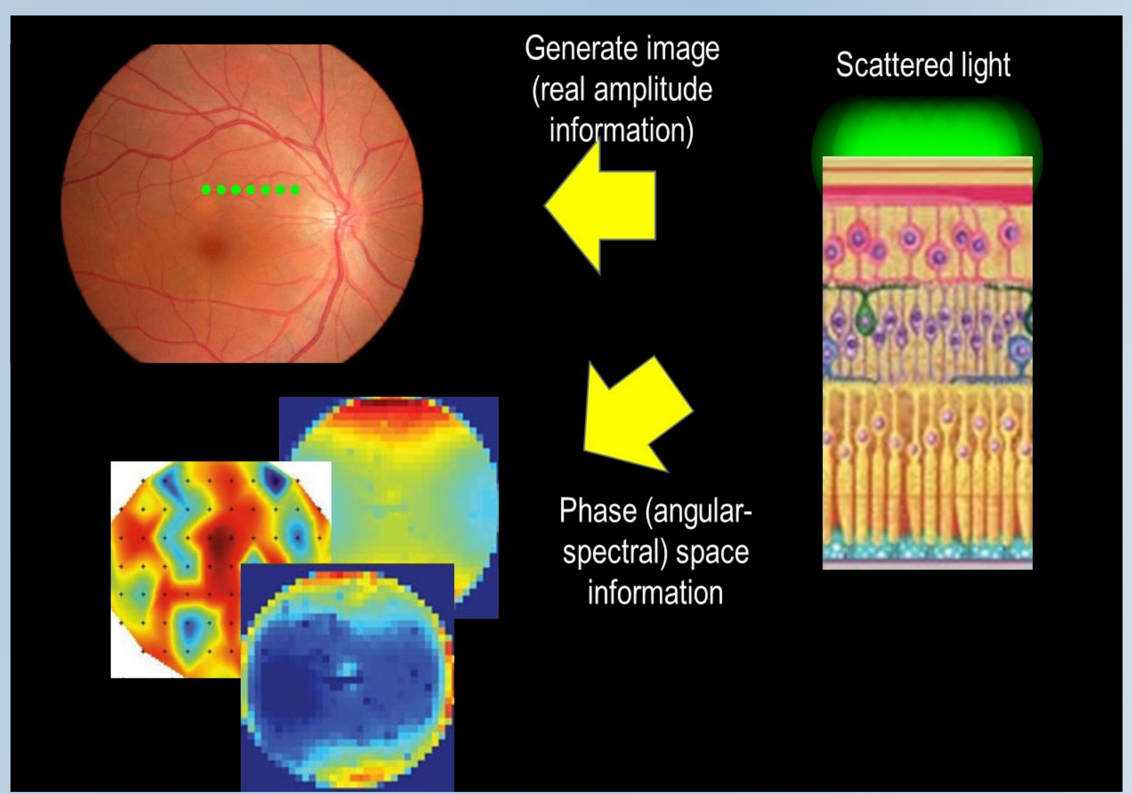

Fig 1. Scatterometry in a nutshell

METHODS

Our system (figure 1) used one of three lasers of different wavelengths (532nm, 785nm and 915nm). The beam was expanded to create a parallel beam with uniform spatial distribution in the plane of the eye. The reflected light from the eye is then directed onto both a refractometer and our scatterometric measurement system. The refractometer is used to account for eye aberrations (mainly defocus) in the result analysis. The scatterometer is comprised of an off-axis parabolic mirror and an array detector in its focus. The pattern formed on the array is in a Fourier conjugate plane to the pupil of the eye, therefore it represents the angular distribution of the light emanating from the eye.

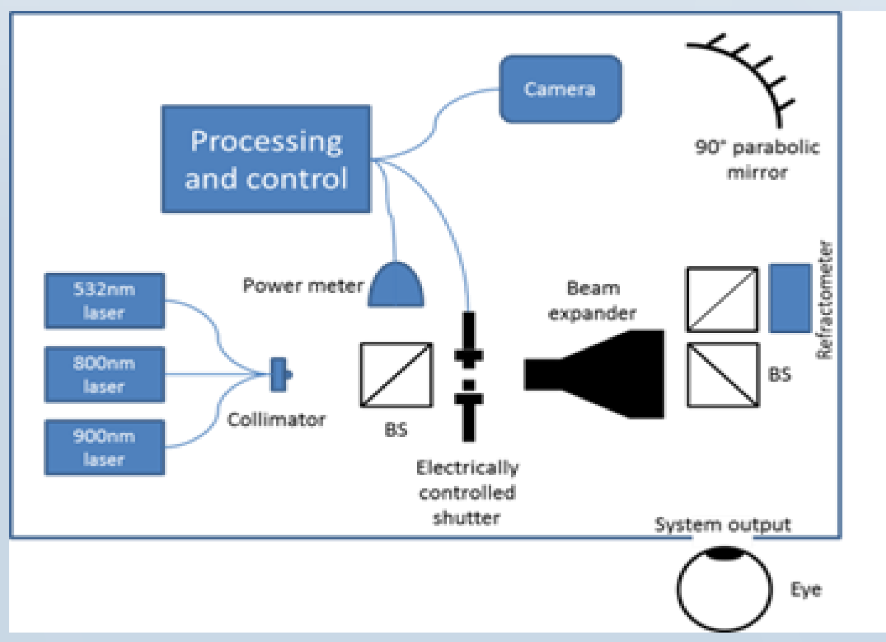

Fig. 2 Ophthalmological scatterometer system schematics

METHODS

The experimental procedure included calibration of the system to allow for absolute power measurement off the array detector as well as for measurement of targets with well-known optical characteristics.

Calibration was done to enable absolute measurement of reflected light from the targets. The angular distribution of the reflected light from the optical system is captured by the measurement system as $B\left[\frac{mW}{str}\right]$. This distribution is an inherent characteristic of the optical system and can be used for complete optical reconstruction of the system. The camera used in the measurement was calibrated to read power as a function of solid angle.

RESULTS

Figure 3 presents preliminary measurement of different targets at different wavelengths. It shows a distinct signature for each target for each wavelength

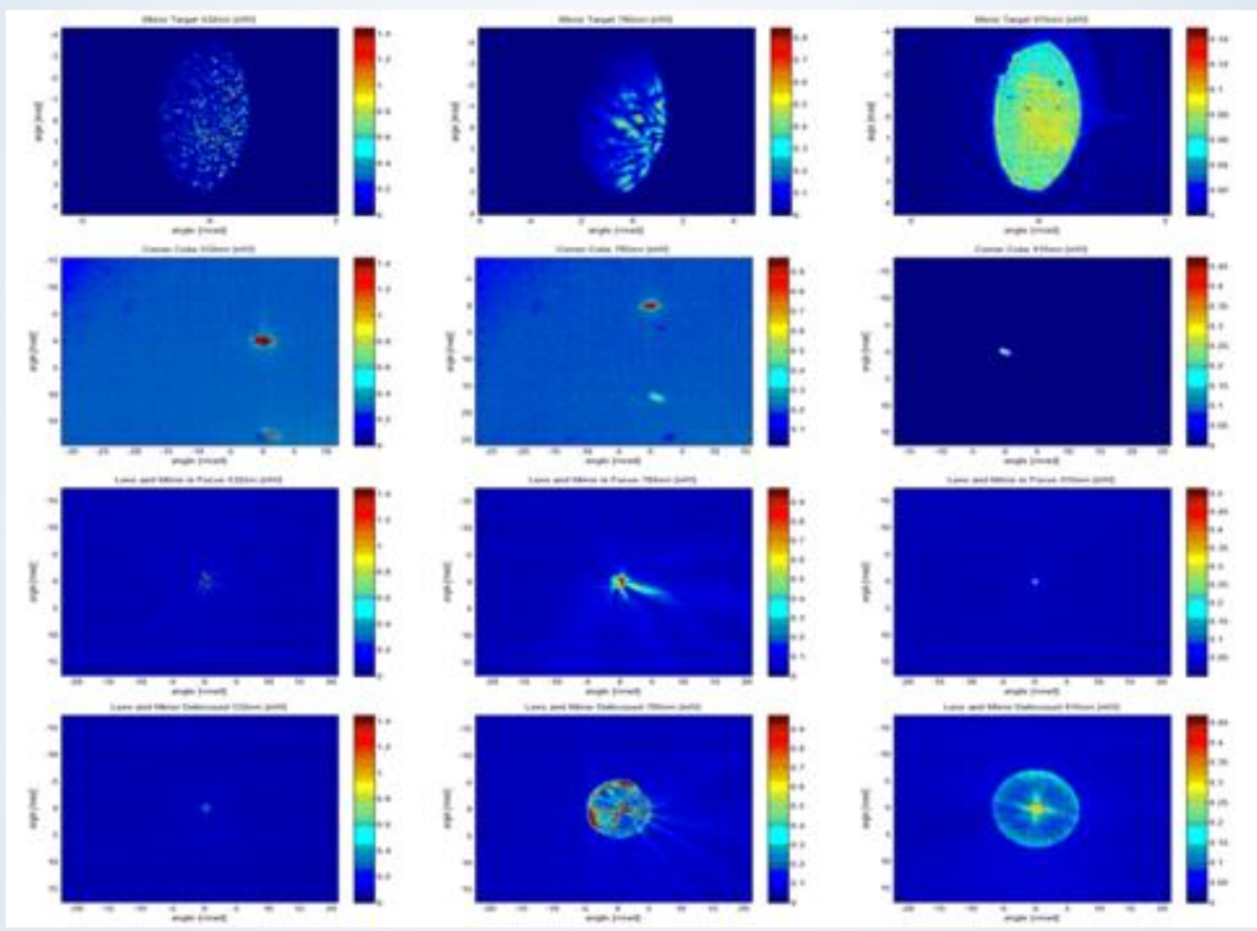

Fig 3. Calibrated measured signals from different targets (rows) and different wavelengths (columns).

Let us now consider the lens and mirror images only. And add the information from the refractometer:

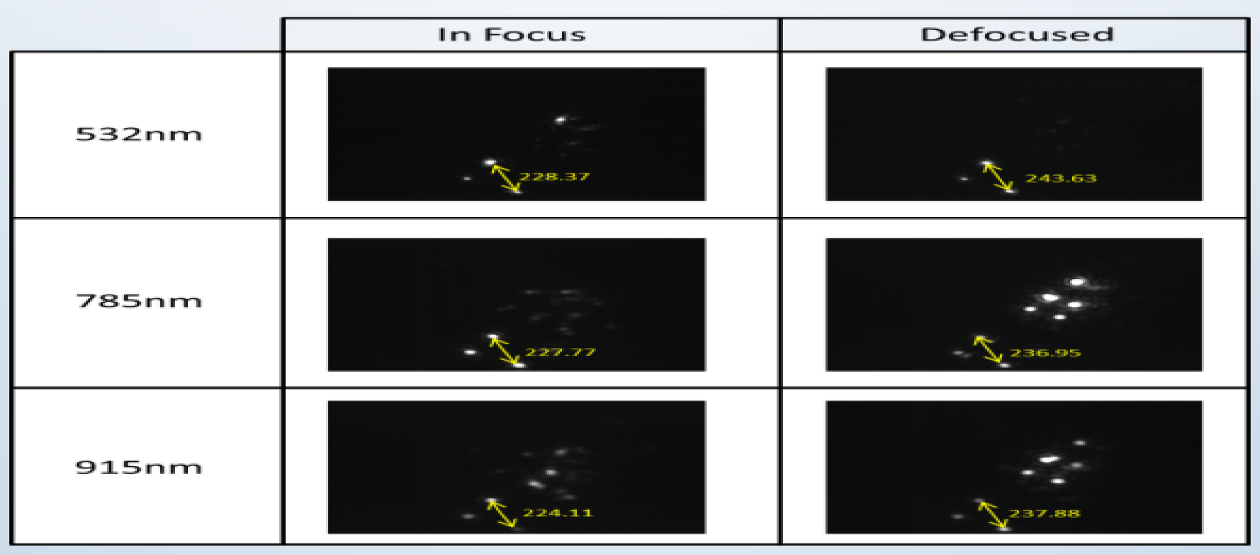

Fig 4. Refractometer image analysis.

Knowing the distance between the pinholes and the CCD chip to be 37mm, the camera pixel size to be 5.2□m, the distance between the pinholes and the target to be 150mm and the target lens to be 22mm in diameter and have a focal length of 11.1mm, we can calculate the defocus angle to be 0.268rad which corresponds with the mechanical measurement of defocus of 0.277rad.

Following a simple deconvolution analysis we can reconstruct the focused image out of the defocused image (figure 5).

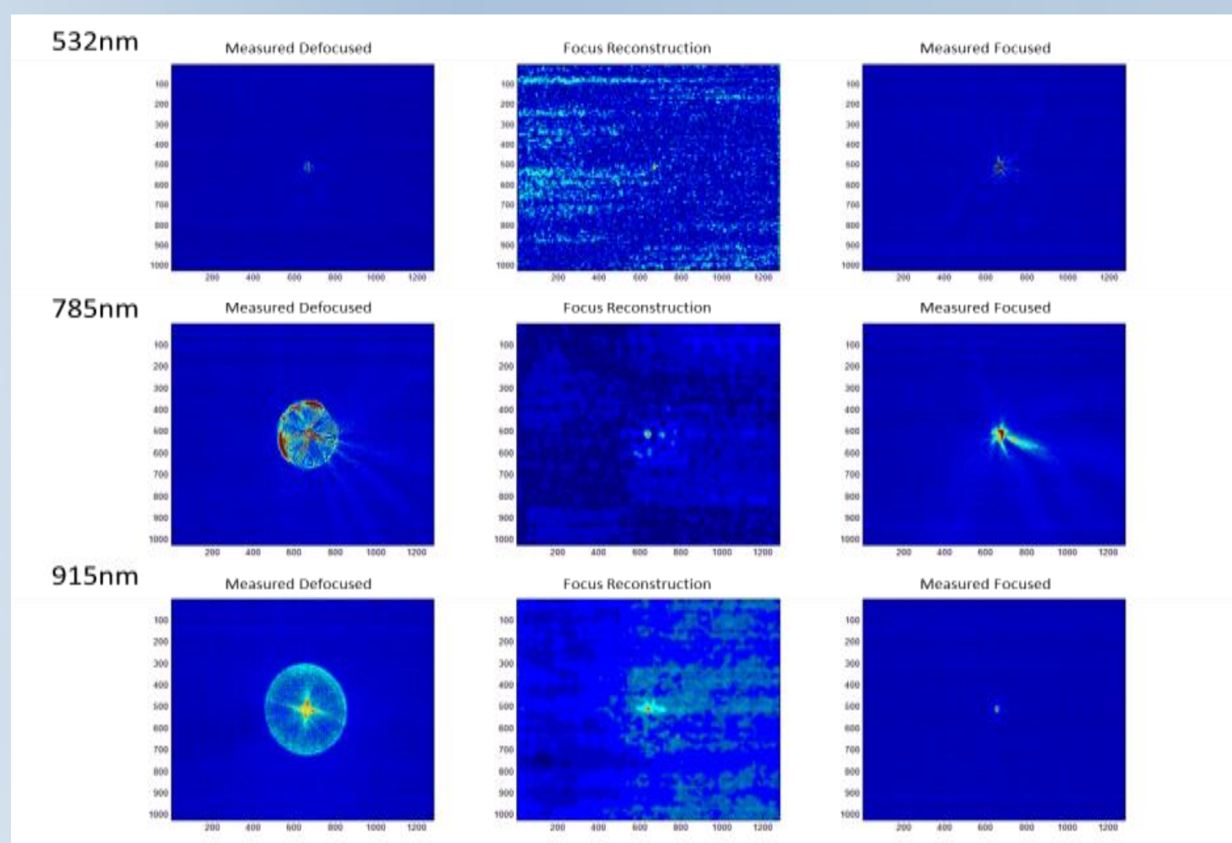

Fig. 5 Image reconstruction. First column is the original image, second column is the reconstructed image and third column is a focused image for comparison.

CONCLUSIONS

1. **Multi-spectral (and in the future hyperspectral) scatterometry holds great potential for medical applications and will enable unprecedented characterization of tissue by use of optical signatures.**
2. **Human trials of a healthy population will establish a baseline and determine population variation standards.**
3. **Various diseases are of interest including:**
   - **Age-Related Macular Degeneration**
   - **Diabetic Retinopathy**
   - **Macular Hole**
   - **Retinal Detachment**
   - **Retinitis Pigmentosa**