05/02/2018

Imaging Characterization of Ultra-Wide Field AR/VR Lenses

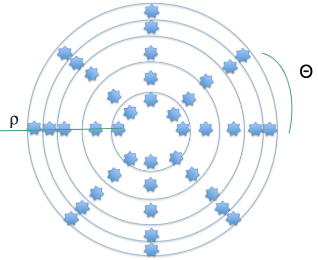
Participants: Barry Magenya (Project Coordinator), Mike Brunsman (Customer Liaison), Mitch Soufleris (Scribe), Aaron Michalko (Faculty Advisor); **Customer: Raptor Vision LLC**

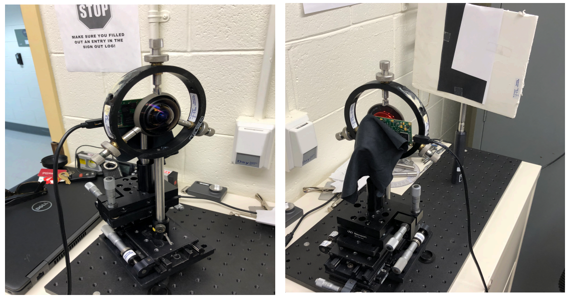
GOAL/OBJECTIVE: To design an application-specific, field-varying resolution classification of the fisheye camera lens for use in a VR/AR video streaming system.

From left to right: Entaniya fisheye lens with 280° field of view, Pixelink PL-E533CU camera and circuit board and sensor.

Diagram of measurements across field and angles at which measurements will be taken (below).

r_1	0
r_2	45
r_3	54
r_4	75
r_5	87
r_6	120





Front and Back views of final test set-up (above).

TEST: Rotated the lens around L-shaped target and conducted slanted edge MTF tests at various points in the field. Record resolution data across the entire FOV at specific locations in equally weighted circles around the field.

- Took 11 rho rotation measurements at the angles across 8 symmetrical theta rotations every 45°.
- Total: 88 total measurements.

MAJOR RESULTS:

- Lens had consistent performance out until 87 deg.
- As expected, the lens performed worse at the edges of the field than towards the middle.
- Due to constraints of the mount of the lens, no information was available from 87-120 deg. which could have informed to the decay of the resolution.

Read the full report:
http://www2.optics.rochester.edu/workgroups/knox/myweb/OPT310.html

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05/04/2018

The Institute of OPTICS

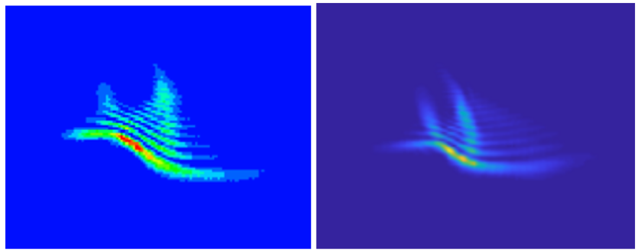
Improved Method of Estimating Required Vision Correction

Participants: Ali Hashim (Project Coordinator), Diego Martinez (Customer Liaison), Perry Wang (Document Handler), Weidi Liu (Scribe), Dr. Jennifer Hunter (Faculty Advisor); **Customer: DigitEyez**

GOAL: To develop a digital visualization image simulation (VIS) tool to simulate how a patient's eyes will perform in a routine eye exam.

OBJECTIVE: VIS tool will aid in providing accurate prescriptions for eye care while reducing the time, cost, and human error currently associated with the common exam routine.

PSF found using perfect lens was modeled with hard-coded Zernike coefficients using Code V (left) and using MATLAB VIS tool (right) to confirm consistency of the VIS tool. Both PSFs are inverted due to negative magnification.



APPLICATION: MATLAB VIS tool capabilities include

- Produce a retinal image using Zernike coefficients from a patient.
- Accounts for apodization of the eye to mimic the Stiles-Crawford effect at the retina.
- Produce a polychromatic PSF used to produce an RGB image.
- Accounts for the toric nature of the cornea by allowing the use of an elliptical-pupil function.
- Provides image quality metrics including the Visual Strehl Ratio .
- Computes an ABCD matrix based on the Diaz paper to find the effective focal length of the crystalline gradient index of the eye.

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J. A. Díaz, "ABCD matrix of the human lens gradient-index pro le: applicability of the calculation methods," Appl. Opt. 47, 195–205 (2008).APOPAI0003-6935 http://dx.doi.org/10.1364/AO.47.000195

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L. N. Thibos et al, "Accuracy and precision of objective refraction from wavefront aberrations," Journal of Vision, vol. 4, (4), pp. 329, 2004.

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Williams, D. R. (2003). Subjective image quality metrics from the wave aberration. Paper presented at the 4th International Congress of Wavefront Sensing and Aberration-Free Refractive Correction, San Francisco, CA.

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Read the full report:
http://www2.optics.rochester.edu/workgroups/knox/myweb/opt310-311-files/2017/311/vision-Final DDD.pdf

05/06/2018

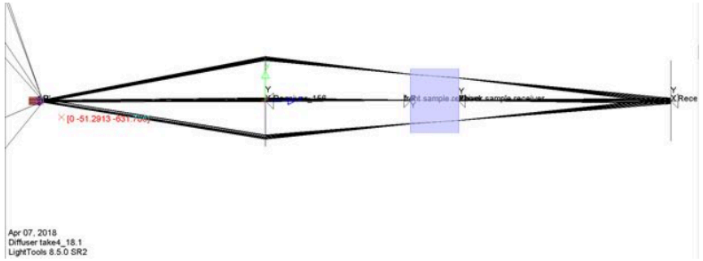
Safe Near-Infrared Surgical Trainer for Urologists

Participants: Katie Armstrong (Project Coordinator), Nora Lane (Customer Liaison), Chih-Hsuan Tsao (Document Handler), Joseph Kelly (Scribe), Dr. Greg Schmidt (Faculty Advisor)

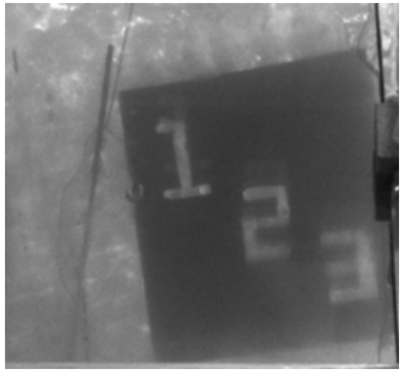
Customer: UR Urology / Dr. Ahmed Ghazi

GOAL: To design a near infrared (NIR) imaging system prototype that can be used in surgical simulations to accurately replicate the current technology of x-rays.

OBJECTIVE: This project will allow surgeons to perform practice surgeries in a safer environment and could lead to a higher rate of success.



Optical design of the prototype setup (above).



Bar target and needle in between two layers of 40% Dimethyl sulfoxide sample with skin layer on top (right).

TEST: Tested the prototype's performance metrics:

- MTF measurement to test the resolution quality.
- Spot diagrams to test the off-axis quality.

Also, conducted a sample material study to analyze the effect of solutions in varying concentrations and the performance with varying settings.

MAJOR RESULTS:

- Design and build an initial static prototype.
- Future plans include integrating a mechanical component that will allow for rotation to image at multiple angles, finding a fluid for the fluoroscopy procedure, and designing a switch program to allow for more effective imaging.

Read the full report:
http://www2.optics.rochester.edu/workgroups/knox/myweb/opt310-311-files/2017/311/trainer-DDD Team Trainer FINAL.pdf

05/06/2018

Optical Metrology of Skin Bumps in Tuberculosis Testing

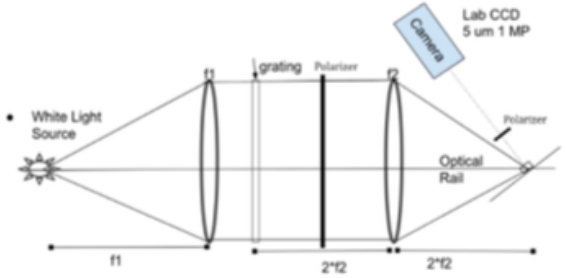
Participants: Sze Wah Lee (Project Coordinator), Rebecca Silver (Customer Liaison), Coco Yang (Document Handler), Madilyn Beckman (Scribe), Yi Wen Fan (Coding Expert), Andrew Berger (Faculty Advisor)

Customer: RN Torres

GOAL: To improve accuracy of the skin test with Purified Protein Derivative (PPD), the current measuring method for Latent Tuberculosis, via an novel optic system that would calculate the surface topography of the bleb after injection, and provide a volume measurement.

OBJECTIVE: To eliminate subjectivity/ amount of human error associated with the current test.

Schematics of the optical projection. Note: A grating is projected onto the image plane (below).



Final presented system setup (above).

TEST: Developed a MATLAB program to perform Fourier transform, and phase unwrapping on the images. Numerical data was extracted from the shifts of the line pattern which is calculates the height and width of the reaction bump.

Also, conducted *in-vivo* image testing on a raised skin mole under different color LED light to validate their design and test the MATLAB code processing.

MAJOR RESULTS:

- Presented a vertically aligned prototype system to show proof of concept.
- Captured an image and manually ran it through program to produce a 3D model with the quantitative data for the height, length and width of the bump.

References:

1.**Mathematic Theory**: Tavares, Paulo J., and Mario A. Vaz. “Linear Calibration Procedure for the Phase- to-Height Relationship in Phase Measurement Profilometry.” *Optics Communications*, vol. 274, no. 2, 2007, pp. 307–314. 2007.02.038.

2. **Polarizer Theory**: Anderson, R. Rox. “Polarized Light Examination and Photography of the Skin.” *JAMA Internal Medicine*, American Medical Association, 1 July 1991.

3.**Camera**: https://www.theimagingsource.com/products/industrial-cameras/firewire-400-monochrome/dmk31bf03/

4.**Collimating Lens**: https://www.edmundoptics.com/optics/optical-lenses/double-convex-dcx-spherical-singlet-lenses/15mm-dia.-x-20mm-fl-uncoated-double-convex-lens/

5.**Doublet:** https://www.edmundoptics.com/optics/optical-lenses/double-convex-dcx-spherical-singlet-lenses/15mm- dia.-x-20mm-fl-uncoated-double-convex-lens/

Read the full report:
http://www2.optics.rochester.edu/workgroups/knox/myweb/opt310-311-files/2017/311/TB Final DDD.pdf

05/04/2018

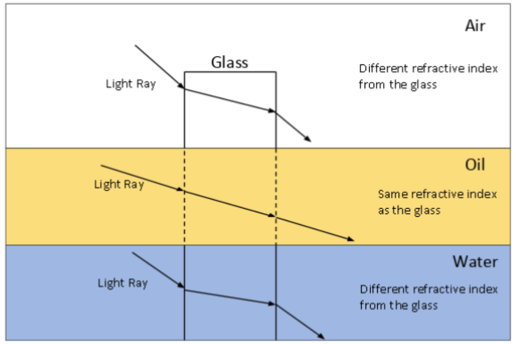
"Invisible Glass" Museum Prototype Exhibit

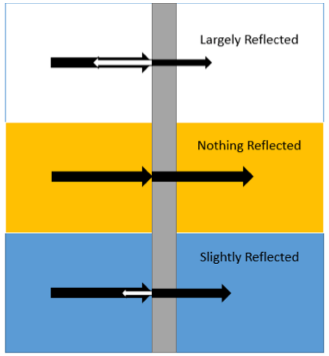
Participants: Haley Knapp (Project Coordinator), Zilong Li (Customer Liaison), Stephen Chess(Document Handler, Scribe), Duncan Moore (Faculty Advisor)

Customer: Rochester Museum & Science Center

GOAL: To create an "invisible glass" prototype exhibit for the Rochester Museum & Science Center as a proof of concept.

OBJECTIVES: To commemorate Katherine Blodgett's work on antireflective coatings and to be an entertaining and educational exhibit to the general public of all ages.





CONCEPT: Creation of "invisible glass" exhibit

- Develop method for preventing the two liquids from mixing when the glass piece is used consistently over a large period of time with potential force.
- Test various refractive indices to determine what refractive indices satisfactorily causes the glass piece to become "invisible."
- To create a caption for the display that offers a simple yet informative explanation of the processes at hand.

MAJOR RESULTS: Designed a "invisible glass" prototype and was able to demonstrate to the public.

Future ideas include the potential of adding lasers and color for increased entertainment as a finalized exhibit.

References:

1. Whelan, M., and Dr. Edwin Reilly. "Katharine Burr Blodgett." *Katharine Burr Blodgett - Engineering Hall of Fame*, Edison Tech Center, 2014, www.edisontechcenter.org/Blodgett.html.
2. "Irving Langmuir and Katharine Burr Blodgett." *Chemical Heritage Foundation*, 30 Oct. 2015, www.chemheritage.org/historical-profile/irving-langmuir-and-katharine-burr- blodgett.
3. Majewski, Janice. "Smithsonian Guidelines for Accessible Exhibition Design." Smithsonian Institution, Smithsonian Accessibility Program, www.si.edu/Accessibility/SGAED#page_21.
4. Nave, R. "Refraction of Light." Refraction of Light, Georgia State University, hyperphysics.phy-astr.gsu.edu/hbase/geoopt/refr.html.

05/04/2018

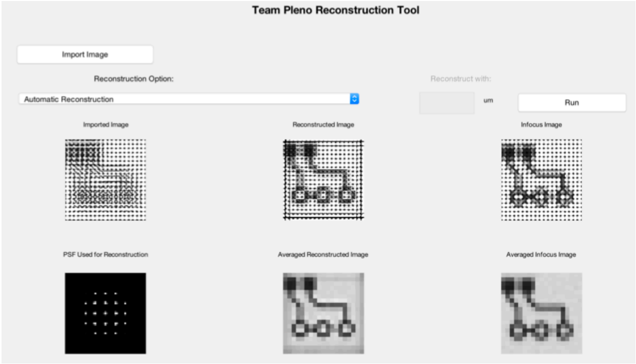
Methodology for Processing Plenoptic System Images

Participants: Wen Zhou (Project Coordinator), Stephen Watson(Customer Liaison), Xiaojing Huang (Document Handler), Weichen Yao (Scribe), Dr. Scott Carney (Faculty Advisor)

Customer: Navitar

GOALS:

- To present a trade study of a plenoptic system with regard to microlens dimensions, sensor type, and image space f/#.
- To provide the image reconstruction tools to implement Navitar's plenoptic lens system.



Demonstration of the MATLAB reconstruction tool (left).

CONCEPT: A plenoptic imaging relies on a set of microlenses in front of the sensor. Each set of pixels behind the microlenses makes up a microlens array.

The microlens array provides a directionality component of light, which allows reconstruction of the image to different defocus depths. However, there is a loss in resolution that reconstructs the image must averages out a microlens array to be one pixel.

MAJOR RESULTS:

- Developed a reconstruction algorithms for an imported image at different defocus positions taken from the plenoptic system in ZEMAX.
- Future work includes creating an algorithm to characterize the system design, generating the PSF for images with changing f/#, pixel size, or other inputs, and updating the script to determine the bounds of the reconstruction.

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Read the full report:
http://www2.optics.rochester.edu/workgroups/knox/myweb/opt310-311-files/2017/311/pleno-DDD Final - Team Pleno.pdf

05/06/2018

Modeling Mid-Spatial Frequency Roughness in Freeform Optics

Participants: David Henry Lippman (Project Coordinator), Kevin Kuyk (Customer Liaison), Wooyoun Kim (Document Handler), Matthew Page (Scribe), Dr. Jannick Rolland (Faculty Advisor)

Customer: Optimax Systems

GOAL: To understand and model how Mid-Spatial Frequency (MSF) error affects the monolithic telescopes.

References:
Tamkin, John M., and Tom D. Milster. "Effects of Structured Mid-Spatial Frequency Surface Errors on Image Performance." *Applied Optics* , vol. 49, no. 33, 2010, pp. 6522.
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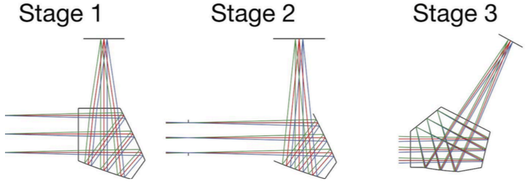
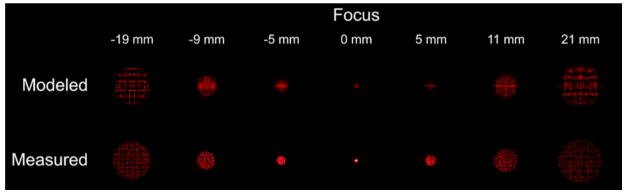
Tamkin, John M., Tom D. Milster, and William Dallas. "Theory of Modulation Transfer Function Artifacts due to Mid-Spatial-Frequency Errors and its Application to Optical Tolerancing." *Applied Optics* , vol. 49, no. 25, 2010, pp. 4825.
Rogers, John R. Slope Error Tolerances for Optical Surfaces, vol. 10316, SPIE, 2007, doi:10.1117/12.725057.
H. Aryan, C. J. Evans, and T. J. Suleski, "On the Use of ISO 10110-8 for Specification of Optical Surfaces with Mid-Spatial Frequency Errors," in *Optical Design and Fabrication 2017 (Freeform, IODC, OFT)* , OSA Technical Digest (online) (Optical Society of America, 2017), paper OW4B.2.
Jason A. Shultz, Hamidreza Aryan, Joseph D. Owen, Matthew A. Davies, and Thomas J. Suleski. "Impacts of sub-aperture manufacturing techniques on the performance of freeform optics."

Three monolithic freeform telescope designs (below).





Comparison of modeled and measured image spots through-focus for the Stage 1 design. All spots are on the same relative spatial scale but not the same relative intensity scale. Both possess the expected MSF signatures (above).

PROGRESS:

(1) Develop model that accurately simulates the effect MSF error has on a system's imaging performance.
(2) Verify the model using empirical measurements for confirmation.
(3) Apply the MSF model to the Stage 3 telescope design to perform sensitivity analysis and tolerancing.

MAJOR RESULTS:

- Concluded the shape and qualitative properties of the focus spots (as shown above) were strongly correlated and supported the proposed MSF model.
- Confirmed the proposed model with empirical through-focus spot measurements.
- Addressed the tolerancing and sensitivity analysis.

Read the full report:
http://www2.optics.rochester.edu/workgroups/knox/myweb/opt310-311-files/2017/311/monolith-TeamMonolith_DDD_RevFinal.pdf

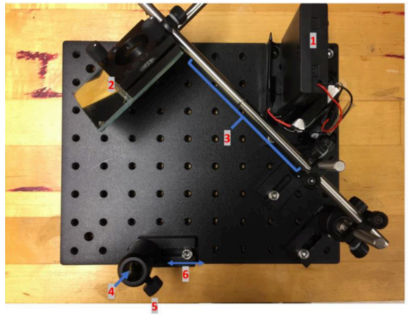
05/05/2018

Instrument for Precise Measurement of Silicon Dioxide Films

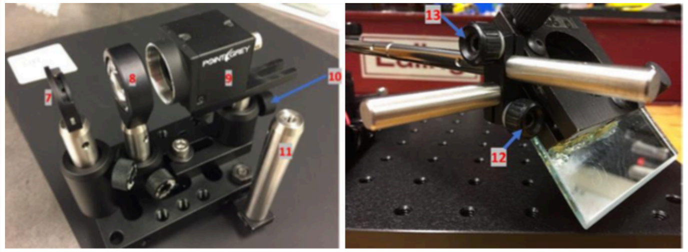
Participants: Yang Deng (Project Coordinator), Zheng Tan (Customer Liaison), Diana Magana (Document Handler, Scribe), Jennifer Kruschwitz & Clarke Eastman (Faculty Advisors); **Customer: J. Kruschwitz / RIT**

GOAL: To develop and produce a dual- angle camera imaging system for determining dielectric thin film thickness in the RIT Microelectronics Cleanroom Lab.

Reference:
[1] Kruschwitz, Jennifer DT, and Roy S. Berns. "Dual-angle, spectral reconstruction imaging method for the determination of dielectric thin-film thickness." Optics letters 42.15 (2017): 3032-3035.



Set-up without imaging board (above).



Imaging board containing the aperture, lens, and camera (left, up). Two knobs next to the mirror (right, up).

TASKS:

- Finished camera gamma calibration.
- Conducted Thicknesses measurement on sample silicon wafers for initial system testing without algorithm analysis.
- Designed, built, and tested a finalized system.
- Developed an algorithm and test on calibration samples.

MAJOR RESULTS:

- In the final system set-up, a white LED source is shined to a mirror that is titled 45° from the z-axis. The light then reflects to the sample, a dielectric thin film on a SiO2 wafer, then back to the mirror. Finally, the light is reflected to an aperture, through a single lens and into an RBG camera.
- A complete MATLAB algorithm matches the reconstructed reflectance for the 15 films on the training sample and 61 thickness samples to a database of film thicknesses.

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Read the full report:
http://www2.optics.rochester.edu/workgroups/knox/myweb/opt310-311-files/2017/311/films-Team_Films_Final_DDD.pdf

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05/06/2018

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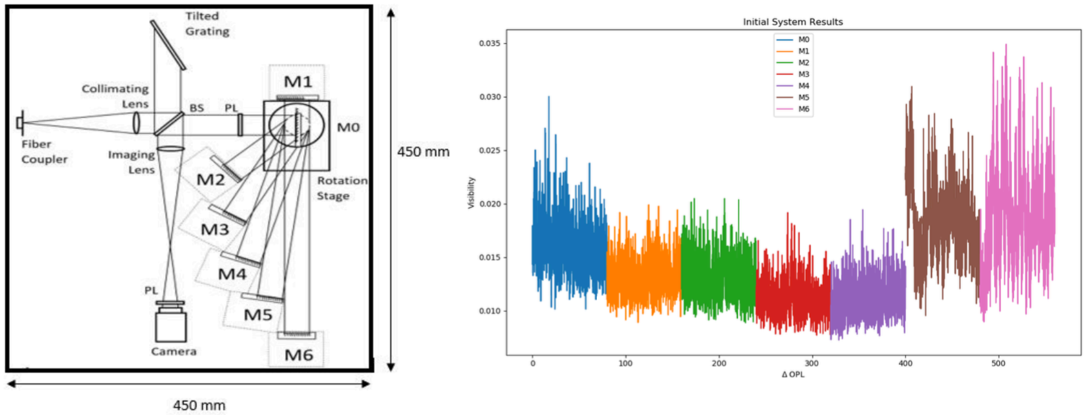
Instrument for Measurement of Coherence Length of Sources

Participants: Maxwell Wolfson (Project Coordinator), Lei Ding (Customer Liaison), Pellegrino Conte (Document Handler, Scribe), Thomas Brown (Faculty Advisor); **Customer: ASML**

GOAL: To design and assemble an interferometer capable of measuring and reporting information regarding the coherence length of a laser.

References:
[1] Paschotta, Rüdiger. "Coherence." Encyclopedia of Laser Physics and Technology - Coherence, Coherent, Light, Spatial and Temporal Coherence, Monochromaticity, 20 Feb. 2017, www.rp- photonics.com/coherence.html.
[2] "Properties of Lasers." Worldoflasers.com, 6 Apr. 2015, worldoflasers.com/laserproperties.htm.
[3] "7 (D.g.). Coherent Light." Andres Robotics and Science, www.goodrichscience.com/7-dg-coherent-light.html.
[4] Vamivakas, Nick. Introduction to Wave Optics.
[5] "Coherence Length." Wikipedia, Wikimedia Foundation, 14 Mar. 2018, en.wikipedia.org/wiki/Coherence_length.
[6] "Helium-Neon Lasers." Sam's Laser FAQ - Helium-Neon Lasers, donklipstein.com/laserhen.htm#henmtmhl.
[7] Customer PowerPoint Presentation [8]
Vladimyros Devrelis, Martin O'Connor, and Jesper Munch, "Coherence length of single laser



Final Design Set-up (left) and Visibility Plot of all lab results (right).

TASKS:

- Developed and updated an interferometer prototype.
- Used FRED to model the impact of diffraction on the system.
- Developed a software analysis method to create a plot of the visibility as a function of optical path length difference through calculating the image along each line of the grating and though calculating the grating line.

MAJOR RESULTS:

- Designed a system to measure visibility every 10 µm and allows for measurements of the coherence length of various sources
- Future plans include investigating artifacts from the beamsplitter and addressing the compactness of the design.

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Read the full report:
http://www2.optics.rochester.edu/workgroups/knox/myweb/opt310-311-files/2017/311/coherence-Team_Coherence_Final_DDD.pdf

05/06/2018

Metastatic Cancer Detection with Second Harmonic Imaging

Hopkins Center for Optical Design & Engineering

The Institute of OPTICS

Participants: Jordan Rabinowitz (Project Coordinator), Yuanchao Wang (Customer Liaison), Ava Hurlock (Document Handler), James Emery (Scribe), Wayne Knox (Faculty Advisor) **Customer: Harmonigenic / Dr. Robert Hill**

GOAL: To optimize the SHG scanning system to better predict metastasis in breast cancer tissue. The metric to predict metastasis is the ratio of the forward to backward ratio (F/B) of scattered light.

References

Francesco Banterle, Alessandro Artusi, Kurt Debattista, and Alan Chalmers. Advanced High Dynamic Range Imaging: Theory and Practice . AK Peters (CRC Press), Natick, MA, USA, 2011.

K.Burke, M. Smid, R. P. Dawes, M. A. Timmermans, P. Salzman, C. H. M. can Deurzen, David G. Beer, J. A. Foekens, E. Brown. Using Second Harmonic Generation to Predict Patient Outcome in Solid Tumors. 2015, *BMC Cancer 15:929.*

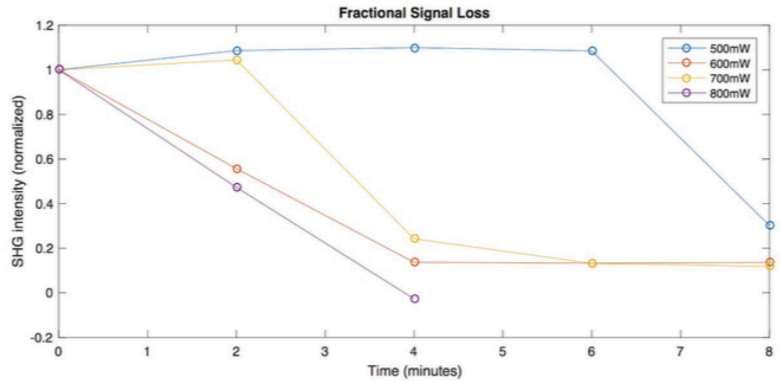
Juan M. Bueno, Francisco J. Avila, Pablo Artal, Comparison of Second Harmonic Microscopy images of Collaged-based Ocular Tissues with 800 and 1045 nm. 2017, *Biomedical Optics Vol. 8 No. 11.*

Pantazis, Periklis et al. "Second Harmonic Generating (SHG) Nanoprobes for in Vivo Imaging." Proceedings of the National Academy of Sciences of the United States of America 107.33 (2010): 14535–14540. PMC. Web. 4 Feb. 2018.

Theodossiou T., G. S. Rapti, V. Hovhannisyan, E. Georgiou, K. Politopoulos, D. Yova, Thermally Induced Irreversible Conformational Changes in Collagen Probed by Optical Second Harmonic Generation and Laser-induced Fluorescence. 2002, *Lasers Med Sci 17:34-41.*

Williams, Rebecca M., Warren R. Zipfel, Watt W. Webb, 2005, Interpreting Second-Harmonic Generation Images of Collagen I Fibrils. *Biophysical Journal Vol. 88* 1377-1386.

Xi. Chen, Oled Nadiarynkh, Sergey Plotnikov, Paul J Campagnola, Second harmonic generation microscopy for quantitative analysis of collagen fibrillar structure. 2012, *Nature America, 10.1038/nprot.2012.009.*



From the graph, 500mW allows for optimized signal for an extended period of time (above).

TEST:

- Analyzed the laser leakage and dark noise correction.
- Calculated the sample damage at high powers and over time.
- Investigated an High Dynamic Range (HDR) toolbox for MATLAB to overcome the dynamic range limitations.

MAJOR RESULTS:

- Optimized the input power at 500mW to increase the signal.
- Recommended that to expose the sample for no more than 5-6 minutes to avoid damage.

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Read the full report:
http://www2.optics.rochester.edu/workgroups/knox/myweb/opt310-311-files/2017/311/cancer-Team Cancer Final DDD.pdf

05/05/2018

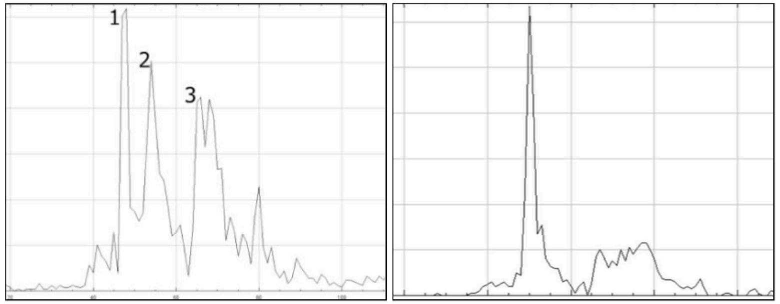
Acoustic Fresnel Lens Design

Participants: Ryan Sauer (Project Coordinator), Nancy Aguilera (Customer Liaison), Yichen Gu(Document Handler), Daniel Graney (Scribe), Wayne Knox (Faculty Advisor); **Customer: URMC / Navalgund Rao**

GOALS:

(1) To design the lens system for an imaging probe used for *in vivo* detection of cancer within the thyroid.

(2) To reduce the signal attenuation that was a consequence of using a biconcave plastic lens to focus the ultrasound signal by exploring a Fresnel lens in this configuration.



Initial Fresnel Signal (left) and Updated Fresnel Signal (right)

TESTS:

- Developed an initial design based on a Fresnel lens, was tested in CodeV, and tested in a lab setting.
    - Lab Test: By the emission of an ultrasonic wave focused by the Fresnel lens onto the transducer array, which captured a signal pulse through time-gating.
- Updated the design for a new zone sag to account for a cleaner signal.
- Tested the surface quality to demonstrate the potential influence on the lens performance.

MAJOR RESULTS:

- Fresnel lens shown to have a considerably less attenuation than the initial spherical biconcave lens.
- However, the lower attenuation value introduced an artifact: a broad secondary signal occurring ~200 µs after the initial peak.

References

"MEASUREMENT REPORT: 3 MHz Matrix Array Transducer" *Imasonic.* RIT. 3 July. 2017.

Francis, Kalloor Joseph et al. "Characterization of Lens Based Photoacoustic Imaging System." *Photoacoustics* 8 (2017): 37–47. *PMC* . Web. 18 Nov. 2017.

"Accura 25 (SLA) Data Sheet." *3D Systems* . 2017.

"Objet 30 Pro Specification Sheet." *Stratasys* . Eden Prairie, MN. 2015.

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