Synthetic Wavelength Holography Automation

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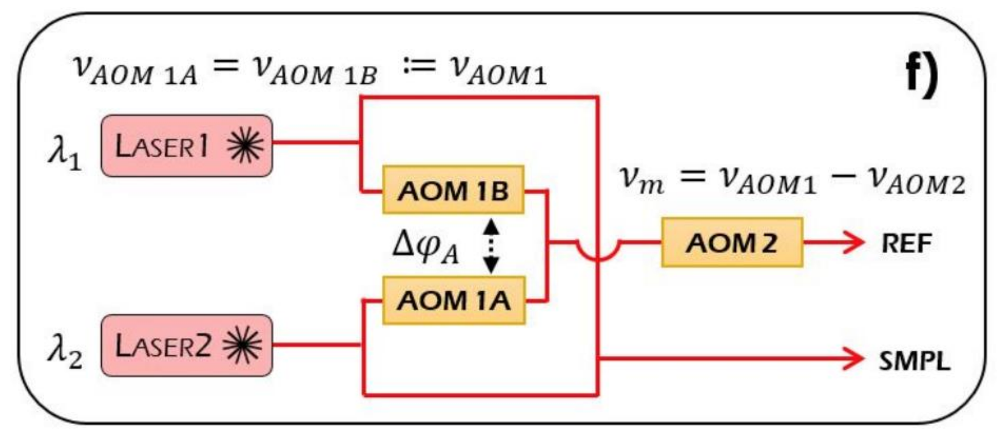
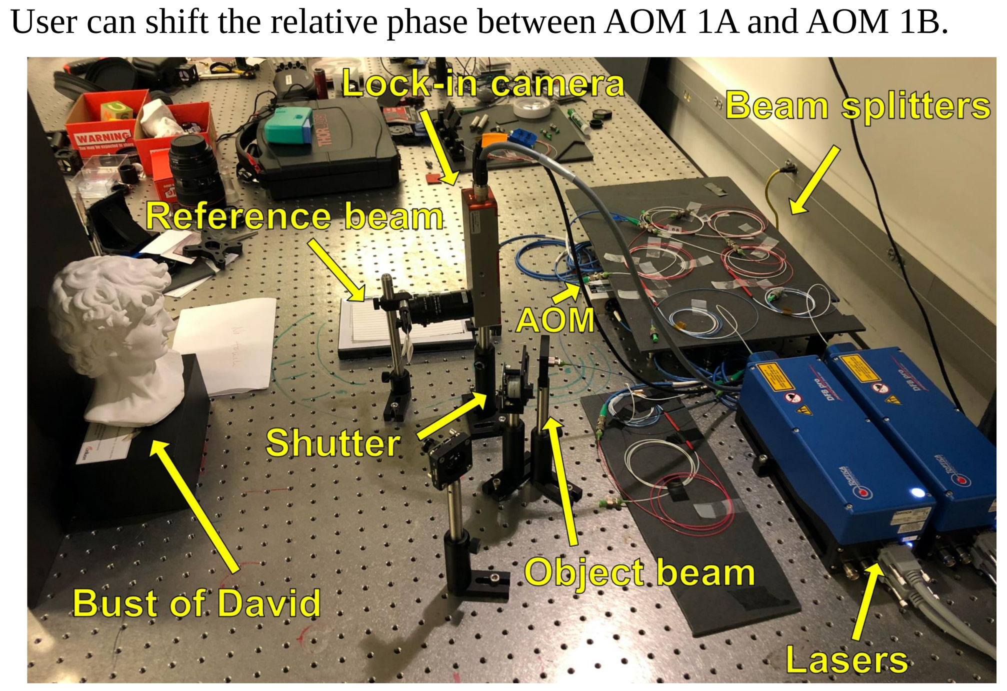
Overview: The process of capturing the images in synthetic wavelength holography is tedious, so we want to simplify the whole process. Meanwhile, the automated setup should still output decent holography.

Introduction

- The lasers and lock-in camera used in superheterodyne interferometry required researchers to manually dial in the temperature settings and clicked the acquire button on the camera GUI. Given that many experiments involve taking multiple measurements, this process can become tedious and unnecessary. We automated this process, namely the researchers only need to enter a set of synthetic wavelengths in the Python shell and the program will automatically calculate and set the corresponding laser diode temperature values, perform the four phase shifts, and acquire the images.
- Our automatic pipeline is identical to the manual acquisition procedure to ensure that the obtained images are reliable, and that no additional errors would be introduced by using the program. We captured a set of imaged using our program to generate a 3D model of a bust of David



Schematics of the laser interferometer setup The 3kHz frequency difference ν_m is achieved using acousto-optic modulators (AOM). User can shift the relative phase between AOM 1A and AOM 1B.



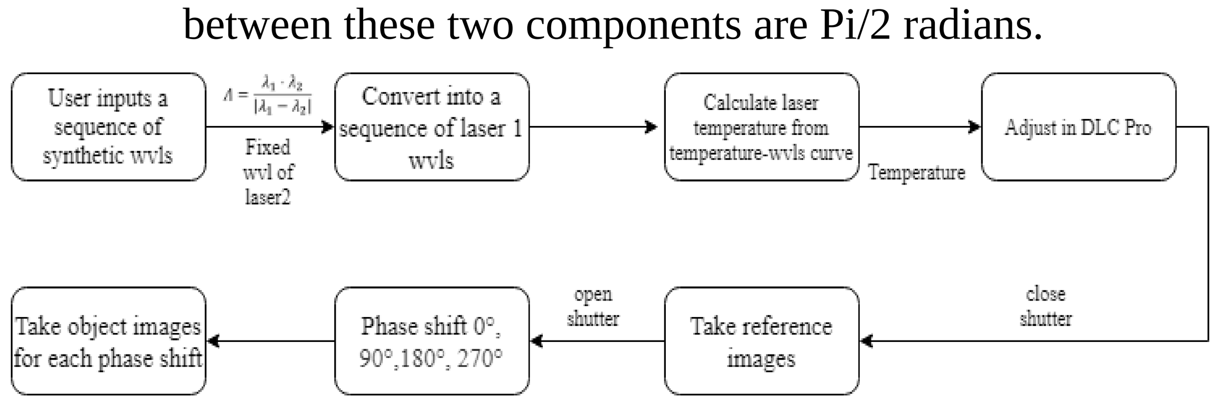
Picture of our actual setup

Methods

Automation Parts:

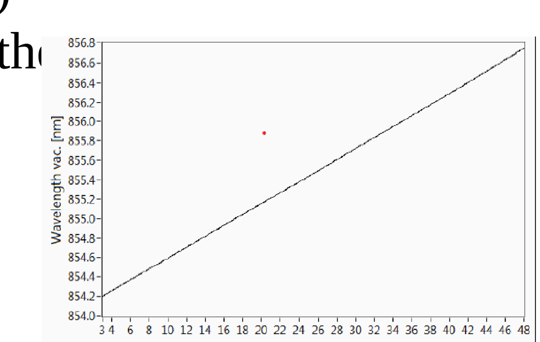
- Picard Shutter: block the object beam during capturing the reference images.
- Moglabs AOM: finish phase shift four time. (0 degree, 90 degrees, 180 degrees, and 270 degrees)
- DLC Pro: use temperature in DLC Pro to change the wavelengths of two lasers.
- Lock-in Camera: capture in-phase images and quadrature images for reference beam and object beam with different phases.

Note: A sinusoid with phase modulation can be decomposed into two amplitude-modulated sinusoids which are in-phase component and quadrature component. The phase differences between these two components are Pi/2 radians.



Capture Process

USB shutter



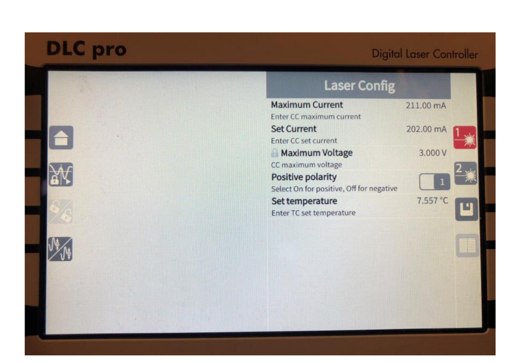
Temperature VS Wavelengths

$$\Lambda = \frac{\lambda_1 \cdot \lambda_2}{|\lambda_1 - \lambda_2|}$$

Equation for synthetic wavelength

We have also captured a set of images manually to compare to our automated measurements. Having acquired our data, we used the images to perform phase wrapping and phase unwrapping. Additionally, a mask would be applied to the phase unwrapped image so it will filter out the undesired areas. Finally, we used a software called CloudCompare to render the points in 3D view so we could get a 3D reconstruction.

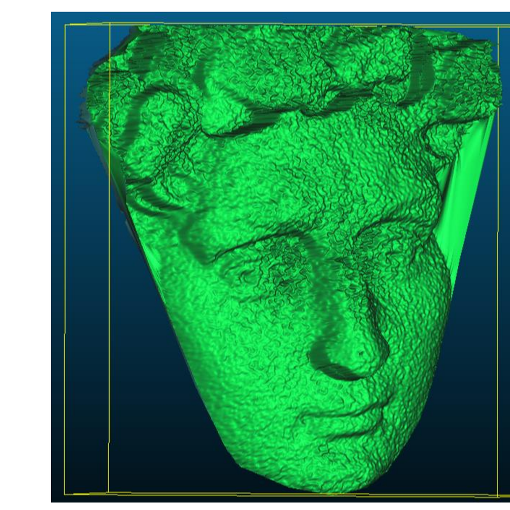
AOM control panel (Moglabs)



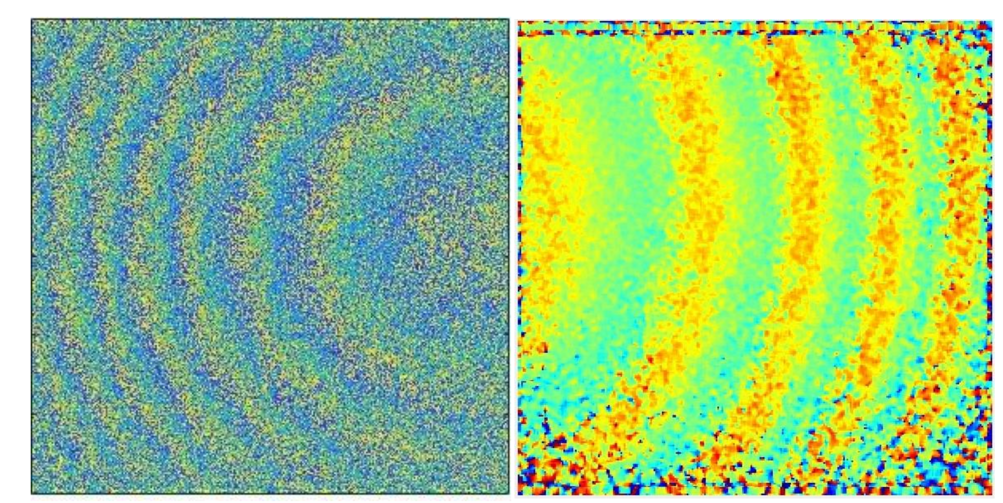
Laser Control Panel

Results

We have successfully controlled our lasers to change its diode temperature using a Python program, and synchronized our shutter, AOM drivers, and lock-in camera to capture a sequence of images at different synthetic wavelengths. Unfortunately, we were unable to reproduce the same accurate 3D model as shown on the upper right corner.



3D reconstruction of the David bust This is from previous year and it's what the result should have looked like after rendering in CloudCompare



Two phase maps The one on the left was captured using heterodyne setup while the one on the right superheterodyne. Notice that the phase map from heterodyning has smoother transitions while our superheterodyning result exhibits more discrete jump.

Having recalibrated our setup, we still got some unwanted results. To get to the bottom of our problems, we tested our superheterodyne setup on a flat cardboard and compared the result against a heterodyne interferometer where only one laser was on at the time and phase shift was not required. Since our heterodyning result was much closer to what we had in mind, we suspected that our AOM driver not phase shifting properly was the root of our problem.

Discussion

In the end we weren't able to recreate an accurate 3D model of the David bust. Neither our automated measurements nor our manual captures produced good results. However, we believe that the cause lies in our lab equipment and we are confident that the automation is working properly. The bottom line is that we have achieved our goal of eliminating most of the manual work during data acquisition and our program can be useful to any future experiments that use similar, if not the same setup.

Potential Applications: Since the synthetic wavelength holography has been proved that it could be used for imaging with scattered wave fronts, we think we can apply this imaging technology in the following scenarios:

- Autonomous vehicles: detect the surroundings in advance during the conditions of heavy fog or heavy rain.
- Medical imaging: diagnose the health conditions under the skin since this technique uses infrared light which has lower risk than X-ray. Also, the processing speed and imaging speed are much faster than the MRI.`

References & Acknowledgements

[1] Willomitzer, F., Rangarajan, P., Li, F., Balaji, M., Christensen, M. and Cossairt, O., 2020. *Synthetic Wavelength Holography: An Extension Of Gabor's Holographic Principle To Imaging With Scattered Wavefronts*. [online] arXiv.org. Available at: <https://arxiv.org/abs/1912.11438> [Accessed 11 March 2020].

[2] F. Li, F. Willomitzer, P. Rangarajan, M. Gupta, A. Velten and O. Cossairt, "SH-ToF: Micro resolution time-of-flight imaging with superheterodyne interferometry," *2018 IEEE International Conference on Computational Photography (ICCP)*, Pittsburgh, PA, 2018, pp. 1-10.