Characterization of Piezoelectric Device for X-ray Adaptive Optics Applications

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Introduction

The Realms project is the initial development of a new kind of adaptive optics for X-ray applications with the aim of reaching high speed actuation in order to steer the X-ray beam at a high speed and enable fast imaging of samples [1]. Additionally X-ray adaptive optics will provide the ability to shape and control coherent X-ray wavefronts at the nanometer level, tuning their properties in novel ways.

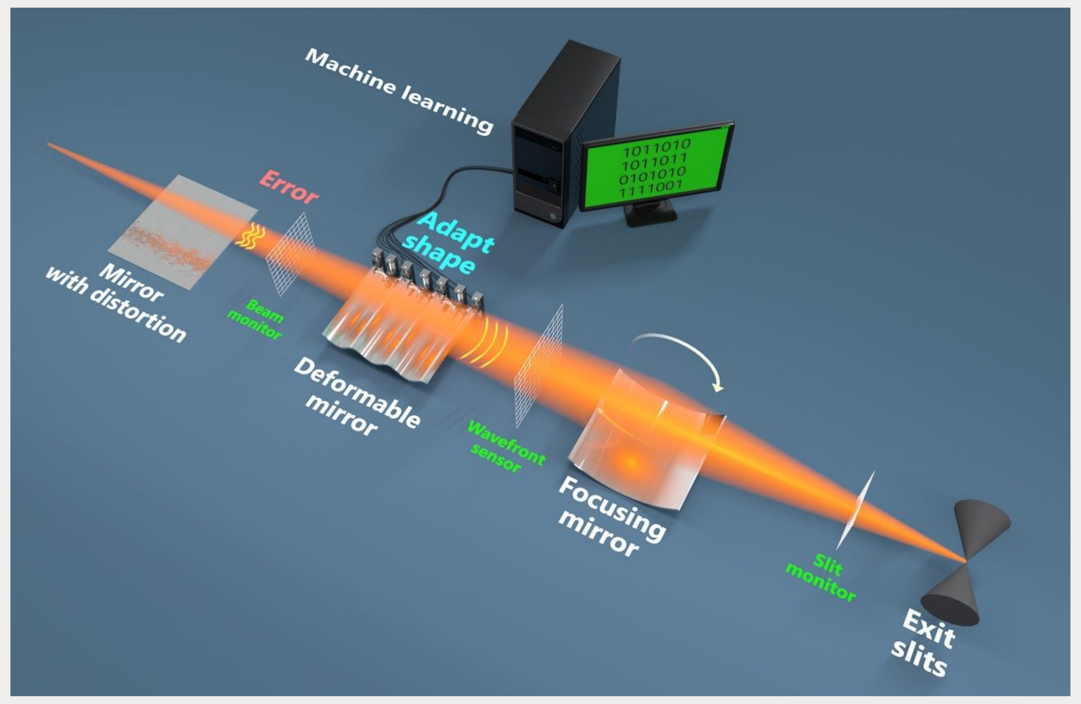

Figure 1 - The Dream Beam will use piezo-actuated substrates to correct distortions and shape the beam

Piezoelectric Device

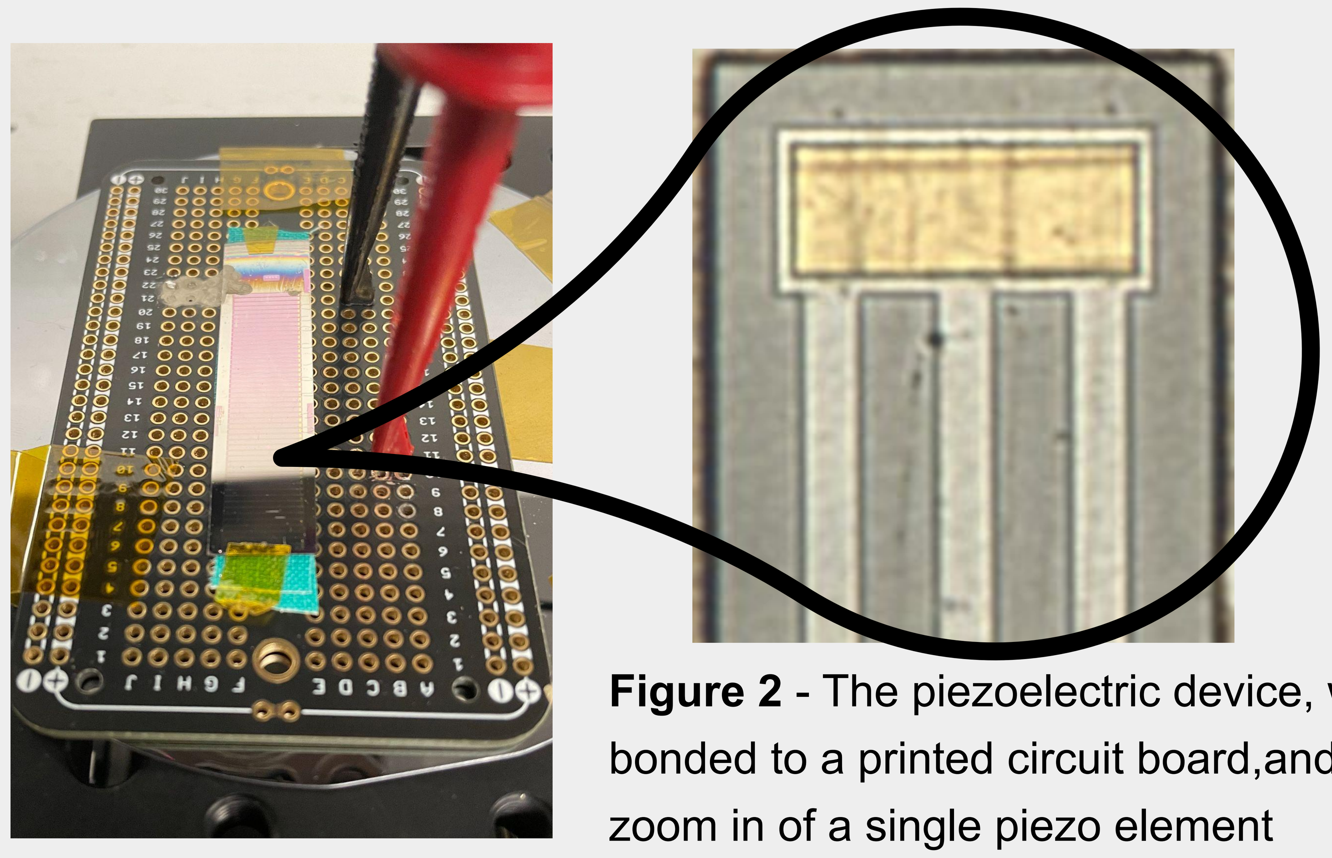

Figure 2 - The piezoelectric device, wire bonded to a printed circuit board,and a zoom in of a single piezo element

We are exploring a new prototype device developed by Penn State University, where the team of scientists demonstrated the capability of the device to steer and focus an ultrasound beam [2]. We want to determine whether the device is a suitable candidate for X-ray applications, where it could steer the beam in reflection, and can be actuated at high frequencies

Data Acquisition

We deployed **EPICS**, a network interface for instrument controls, to enable simple data acquisition in python. This interface is being adapted by the Advanced Light Source, and we **successfully deployed** it in the optical prototyping lab.

Figure 3 - EPICS is short for Experimental Physics and Industrial Control Systems.

Experiments

The experiment consisted of **applying various voltages and frequencies** across the piezoelectric device, and physically measuring the fine displacement of the device with high precision (~1nm) and high speed (>10kHz) to study its dynamic properties. The data was collected from a **laser interferometer,** to measure the height displacement of the piezo actuator.

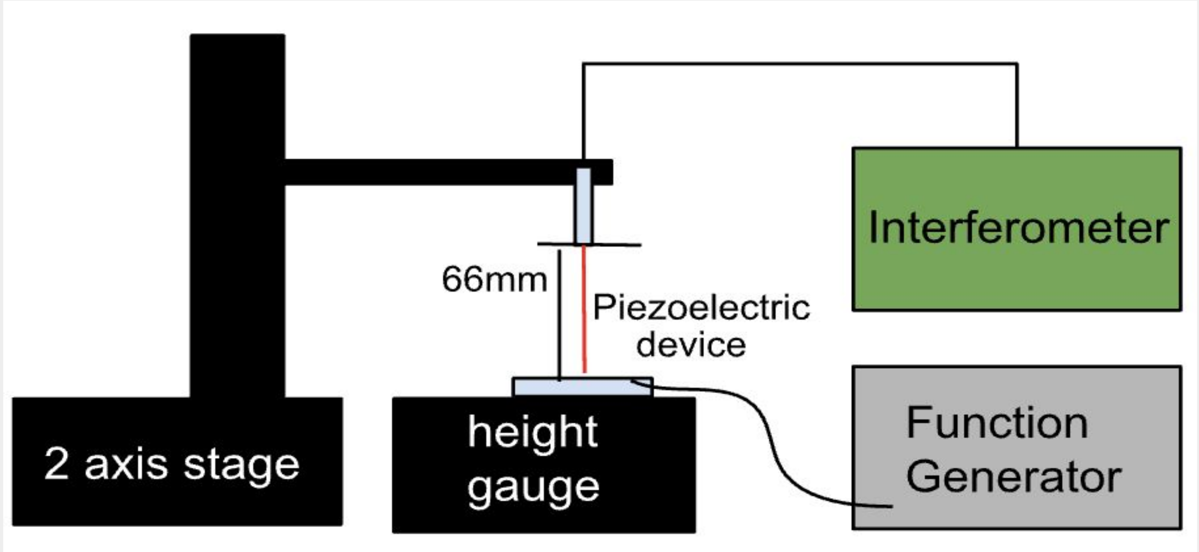

Figure 4 - The interferometer head is held by a post that is on top of a 2 stage axis. The piezoelectric device is on top of a height gauge. The output of the function generator is connected to the device.

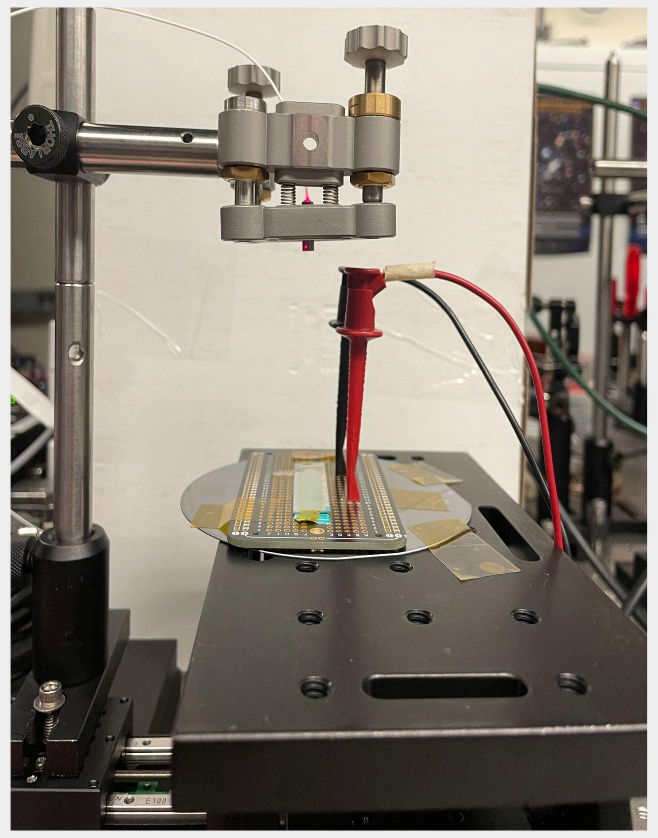

Figure 5 - An interferometer uses properties of light waves to make precise measurements. This interferometer is capable of measuring fluctuations in distance at the pico (10^{-12}) scale.

Results

We successfully collected data and processed it to characterize the piezoelectric device. We found that stimulated at 5V, the device can displace about 7 nanometers.

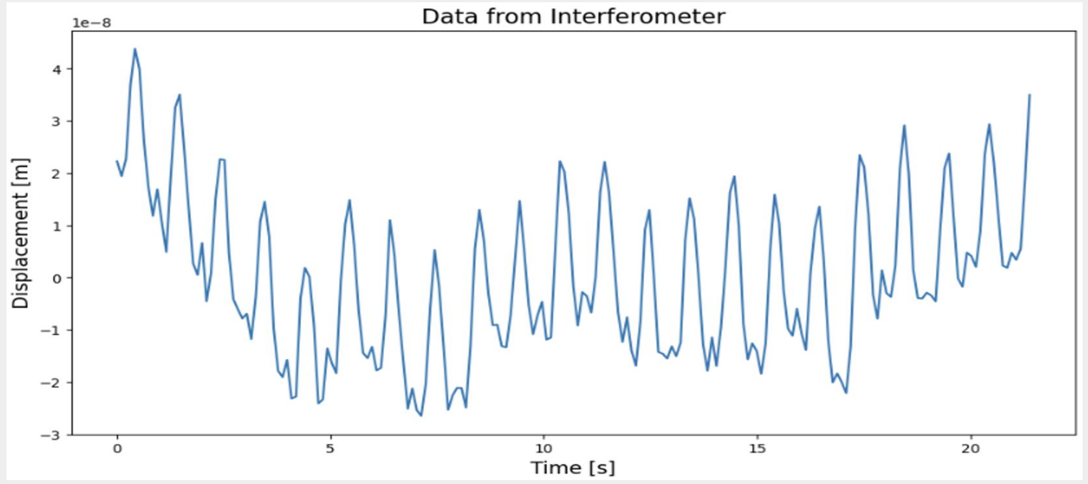

Figure 6 - Data collected from interferometer at a sampling rate of 9.53 Hz

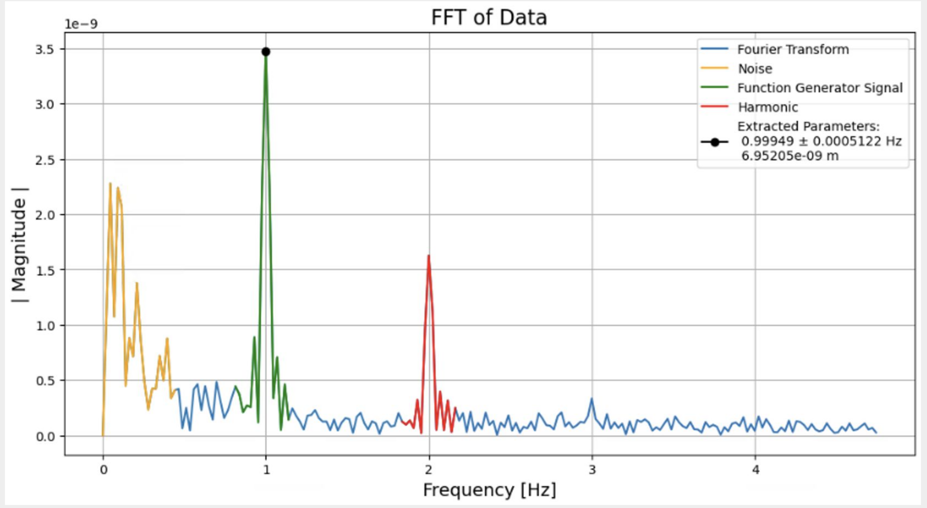

Figure 7 - Fourier transform of the signal showing the spectral response of the piezoelectric device

Conclusion

We demonstrated that the piezoelectric device worked, and characterized some of its properties (sensitivity and frequency response.) We successfully deployed a new instrument controls framework that will allow performing measurement campaigns and help develop new piezoelectric device specifically designed for X-ray applications.

Acknowledgement

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References

[1] dreambeam.lbl.gov
[2] Tipsawat, Pannawit, et al. IEEE open journal of ultrasonics, ferroelectrics, and frequency control 2 (2022): 184-193.