Double-pass Acousto-optic Modulator System

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INTRODUCTION

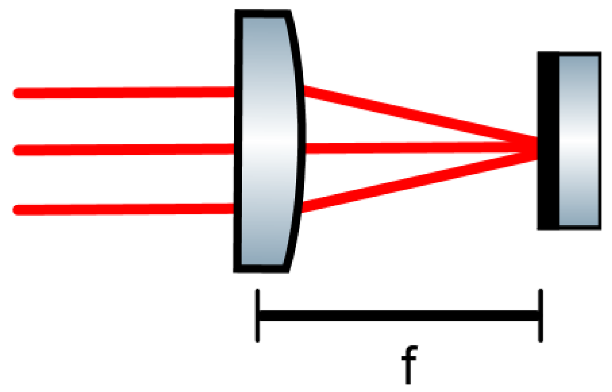
The motivation behind this project was to maintain optical power out of a fiber in part of a quantum optics experiment. The experiment requires a variable shift in light frequency by use of an acousto-optic modulator (AOM). AOMs cause a change in beam direction, leading to issues in maintaining good fiber coupling.

By using a plane mirror to double pass the AOM, light can be frequency shifted without changing beam direction. This cannot be done for a changing frequency shift because the change in beam direction depends on AOM frequency.

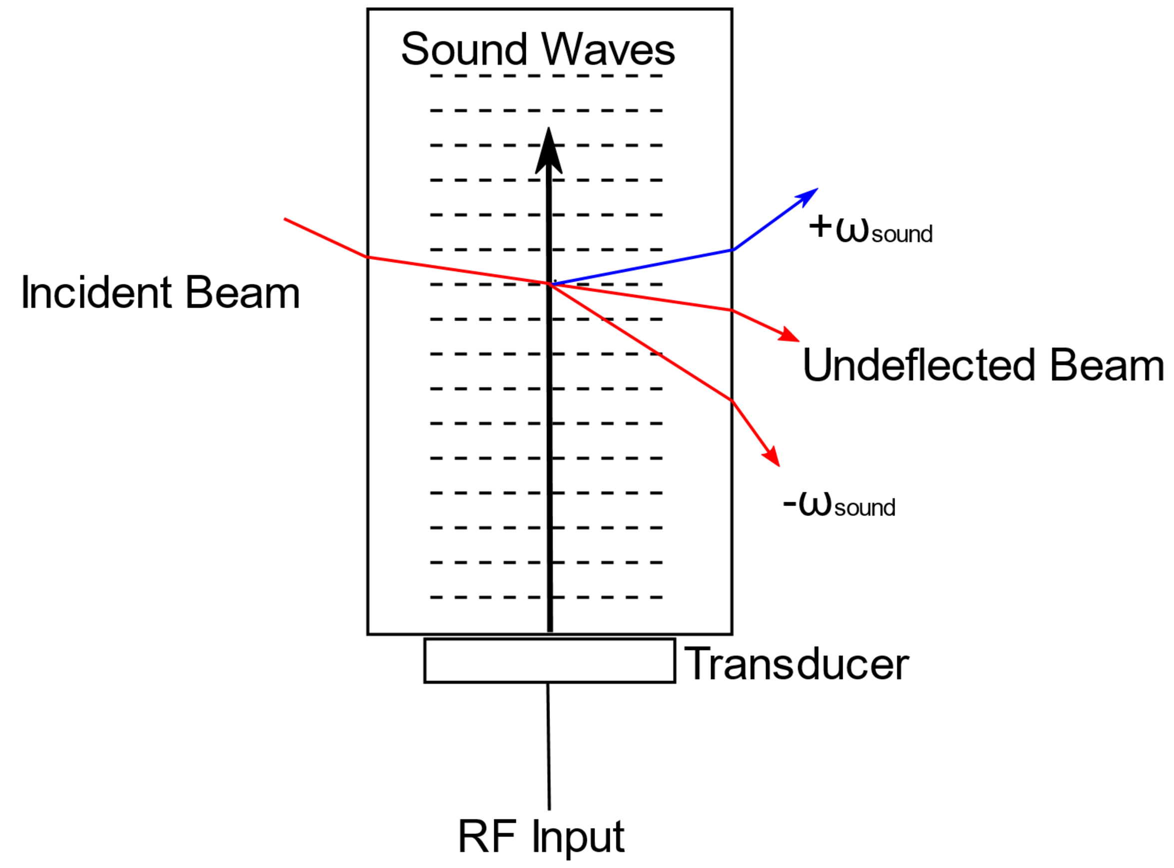
The experiment requires maintaining high double pass efficiency in the AOM, and more critically, high fiber coupling efficiency across a 20 MHz range. A method described in Rev. Sci. Instrum. 76, 063112 suggests that using a cat's eye setup can dramatically improve AOM double pass efficiency and fiber coupling efficiency as AOM frequency is modulated.

BACKGROUND

A traditional Cat's eye is composed of a lens with a plane mirror at its focus. This results in a system that reflects incident parallel light back along the direction of propagation. Depending on the angle of the mirror, the light will gain some displacement from its original path as it returns.

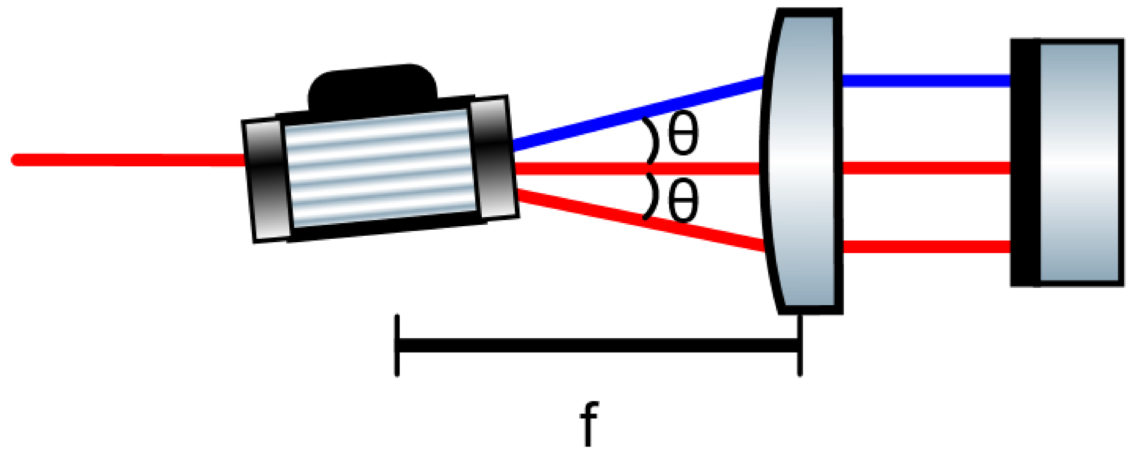


An AOM shifts the frequency of a light beam by the frequency of an applied RF signal. The shift is a result of Bragg diffraction caused by the light wave interacting with a sound wave created by the transducer of the AOM. Light is then deflected at a frequency dependent angle to satisfy the Bragg condition.



DESIGN

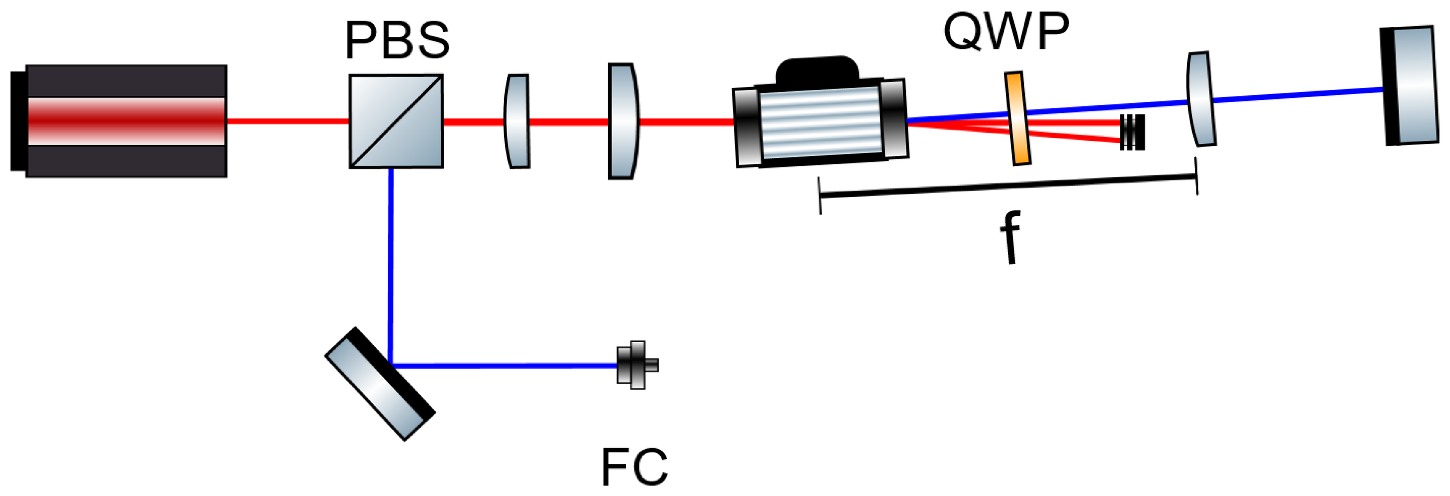
Aligning the cat's eye lens to have its focus in the AOM, allows for the mirror to reflect parallel light back to the lens and have it be refocused along its original path.



$$2\lambda_{sound}\sin\theta = m\lambda_{light}$$

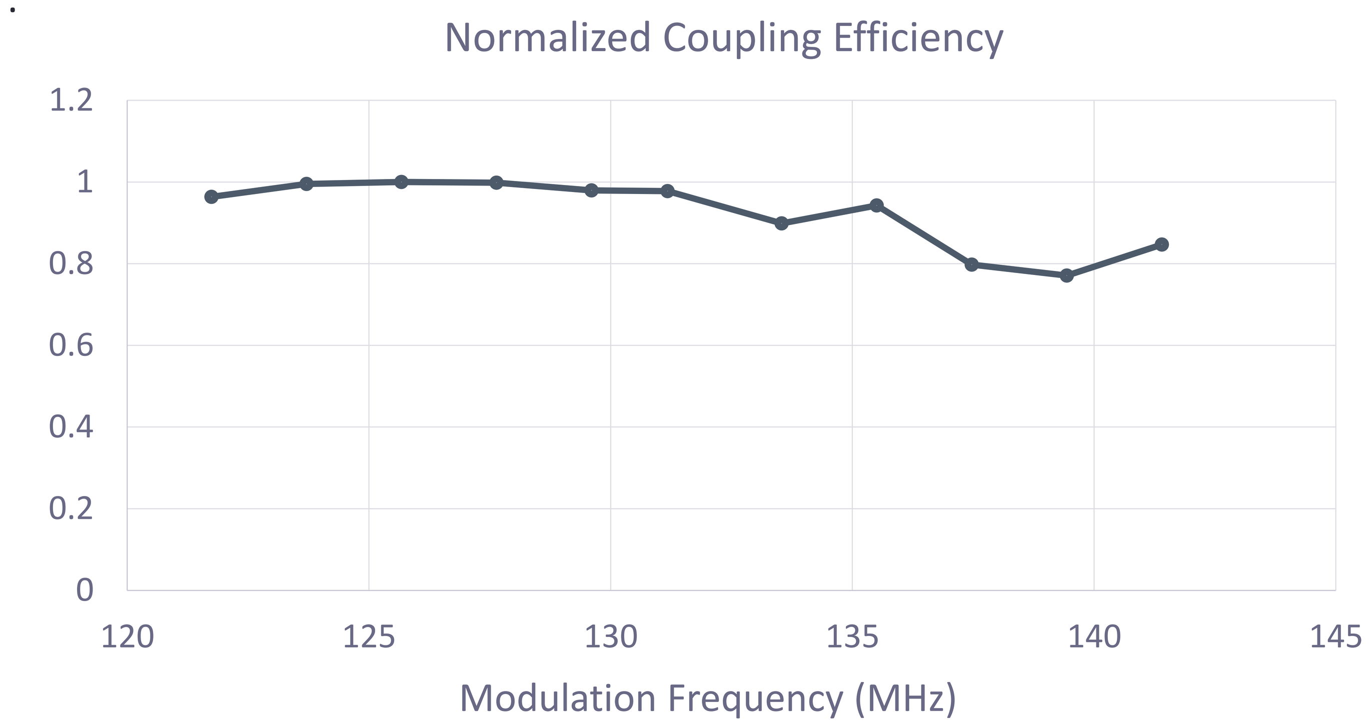
The angle, θ, depends on frequency, but the cat's eye returns all beams collinear to their incoming paths. To prevent all of the diffracted beams from getting double passed beam blocks are placed. Letting only the first order pass into the cats eye, the light returning through the AOM will be single frequency. This light gets frequency shifted again on its return path through the AOM, resulting again in multiple deflected beams. The first order of the return path light works out to be exactly collinear to the original laser and this it needs to be separated.

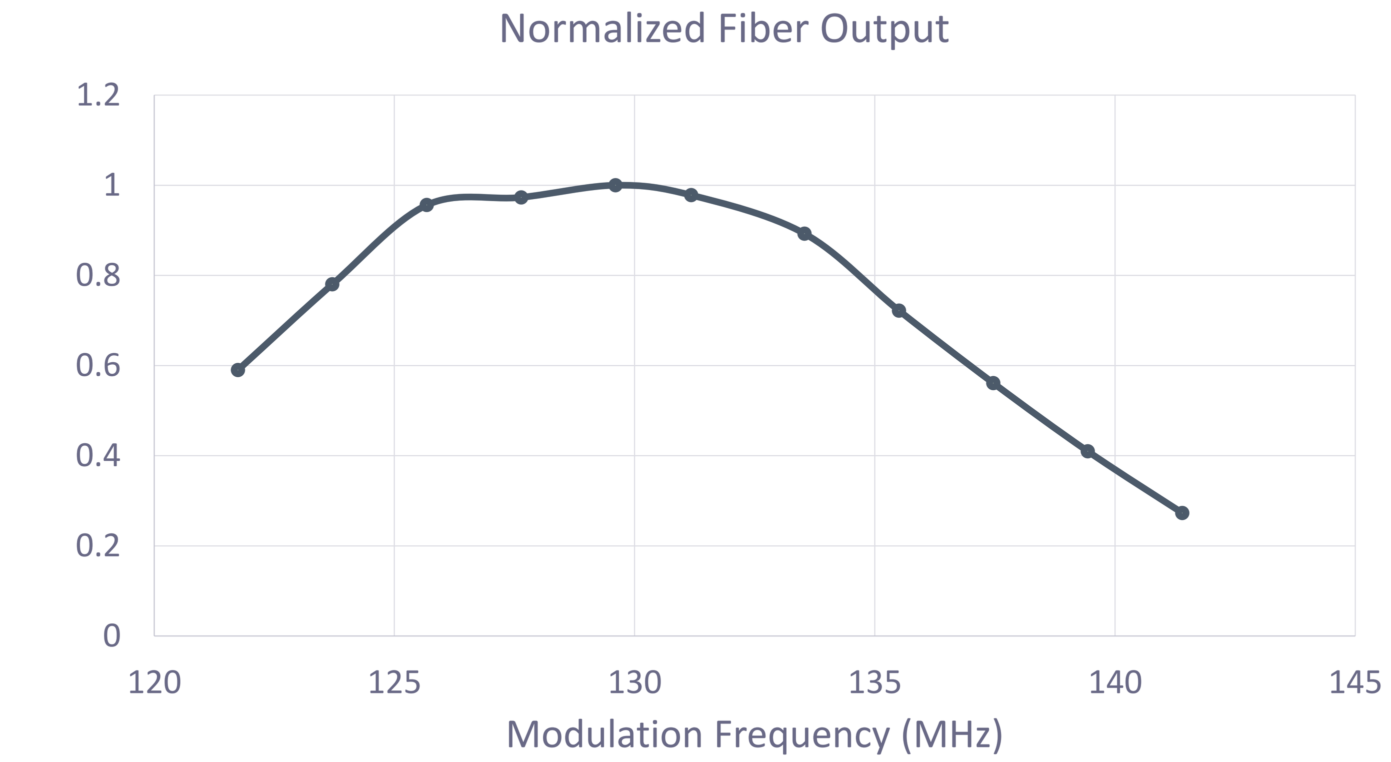
A quarter-wave plate is placed in the path of the beam, the net result of double passing this is a 90° polarization change. This change allows the return beam to be reflected off of a polarizing beam splitter. The first order of the second pass can then be coupled into a fiber for use in the experiment.



PBS= Polarizing beam splitter FC= Fiber coupler QWP= quarter-wave plate to select the frequency shifted light on its return path through the PBS.

RESULTS





Coupling efficiency is quite good over our frequency range of interest (FWHM>20MHz) . The asymmetry in the curve implies that there was a misalignment but due to time constraints, a better alignment was not recorded.

The power output of fiber was desired to be constant within 10% over the frequency range. This goal was not met but could be if AOM output is made more constant through a feed-forward that varies RF power. Additionally alignment would need to be corrected to allow higher coupling efficiency for high frequencies.

REFERENCES & ACKNOWLEDGEMENTS

[1] Rev. Sci. Instrum. 76, 063112 (2005)

[2] Opt. Commun. **266**, 609 (2006)

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