A dynamic subwavelength pitch grating modulator for continuous Time-Of-Flight ranging with optical mixing

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Since continuous Time-Of-Flight ranging systems based on electrical mixing run into fundamental limits we designed an optical MEMS (de)modulator/mixer. With our dynamic (MHz range) subwavelength pitch diffraction grating we demonstrated TOF ranging with optical mixing.

I. Introduction

Continuous Time-Of-Flight (TOF) ranging relies on measuring the time-shift of a modulated carrier wave induced by traveling time. The key component is the electro-optical modulator. Two main research tracks can be identified: modulators in the electrical domain [1] and modulators in the optical domain [2]. The latter allows combining off-the-shelf high performance image sensors with a separate optical modulator, ultimately providing very high image resolution and system performance. In this proceeding we will demonstrate TOF ranging with an optical MEMS-modulator.

II. Mixer/modulator fabrication

In a SOI wafer (top layer monocrystalline Si: thickness t=220nm + buried oxide layer: thickness h=2µm) a diffraction grating with 1.25µm pitch and fill-factor 80% (string width w=1µm) is defined. The diffraction grating is constructed as two intersecting combs each with their own bond pad (Figure 1). Next we deposit a metal stack (150nm Al + 100nm Au) onto the bond pads using a standard lift-off process. To define the freestanding regions (+-25µm string length l) we applied a resist mask after a treatment in a vacuum HMDS oven to ensure good adhesion of the mask. The underetch is performed with wet buffered HF and the samples are dried afterwards using a CO_2 Critical-Point-Drying process to prevent damage due to surface tension.

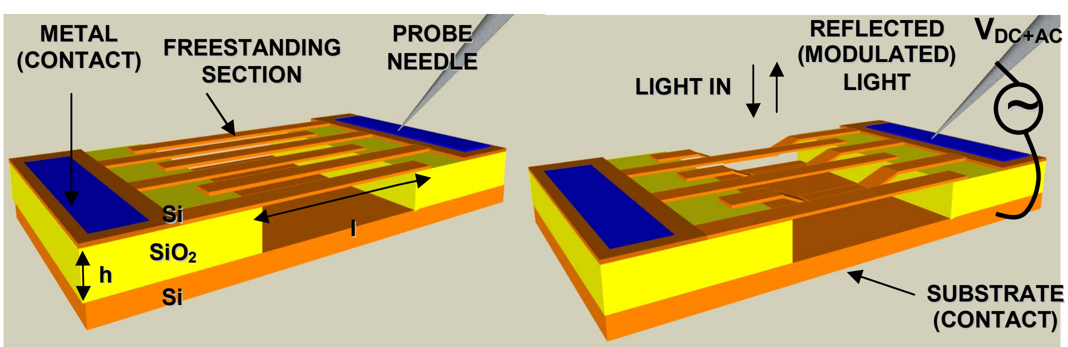

Figure 1: dynamic grating modulator: not-actuated (left) vs. actuated (right)

III. Working principle modulator/mixer

Applying a voltage (V_{AC}=8V, f=2.8MHz and V_{DC}=100V) between grating and substrate creates a closing gap capacitor and a sinusoïdal force with magnitude $F_\omega = CV_{AC}V_{DC}/h$ that deflects the grating beams (driving capacitance $C=\varepsilon_0 lw/h$, ε_0 vacuum permittivity, initial gap h =2μm). Hence the reflected light is modulated at the applied frequency f. Using a spring-mass-damper model we find a typical vibration amplitude of 160nm which is sufficient for modulation depths up to 40% (experimental value) for λ =1.54μm. Since the grating pitch is smaller than λ, only one diffracted order is present.

IV. Time-Of-Flight with optical mixing

The modulated laser light ~sin(2πft) is send through a fiber and reaches the mixer with a phase delay φ(L) dependent on the fiber length L. We apply a phase difference ψ between modulated laser and mixer thus the reflected light is proportional with sin(2πft-φ)*sin(2πft+ψ). The reflected (mixed) light is separated from the incoming light with a circulator and sent to a photodetector. Since the reflected DC optical power P_{DC} has a component ~cos(ψ+φ) we can extract the fiber length by measuring P_{DC} with alternating ψ (0°,90°,180°,270°) and compare with the real fiber length (Figure 2).

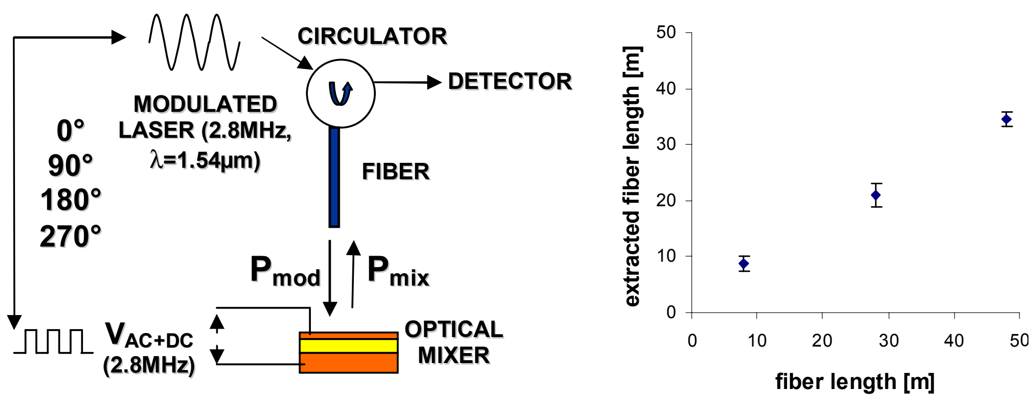

Figure 2: TOF-setup (left) and extracted fiber lengths (right)

V. Discussion + perspectives

Our TOF-technique predicts the fiber length well for the smallest fiber length but underestimates the fiber length for the two longer fibers. We suspect this might be due to higher order components (3f, 5f) that can also mix to the DC-level. In our future work we will eliminate this effect and construct a system that is able to process complete images.

VI. Acknowledgement

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References

[1] R. Schwarte, Dynamcic 3D-vision, International Symposium on Electron Devices for Microwave and Optoelectronics Applications, Vienna, Austria, 2001, pp. 241-248

[2] W. Van der Tempel et al., State-of-the-art modulator approaches for continuous time-of-flight range finding, annual symposium of the IEEE/LEOS Benelux Chapter, Brussels, Belgium, 2007, pp. 63-66