MEMS SENSOR FOR MEMS METROLOGY

IAB Presentation

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OUTLINE

- INTRODUCTION
  - Motivation
  - Contact/Noncontact measurement
  - Optical interferometer
  - Research goal
- MICROINTERFEROMETER
  - Modeling and system analysis
  - Fabricated micro lens sample
  - Microphone scanning by fabricated sensor
  - System integration
- CONCLUSION

MOTIVATION

- MEMS Products
  - Small devices
  - Many devices on wafer. Usually periodic in array
  - Dynamic, moving structures
    - Sensor: microphone,accelerometer,pressure sensor
    - Mechanical actuator
- MEMS Metrology
  - 25% of cost of products sold spend on quality inspection
    (10% in the semiconductor industry)
  - 40-70% product yield
    (90% in the semiconductor industry)

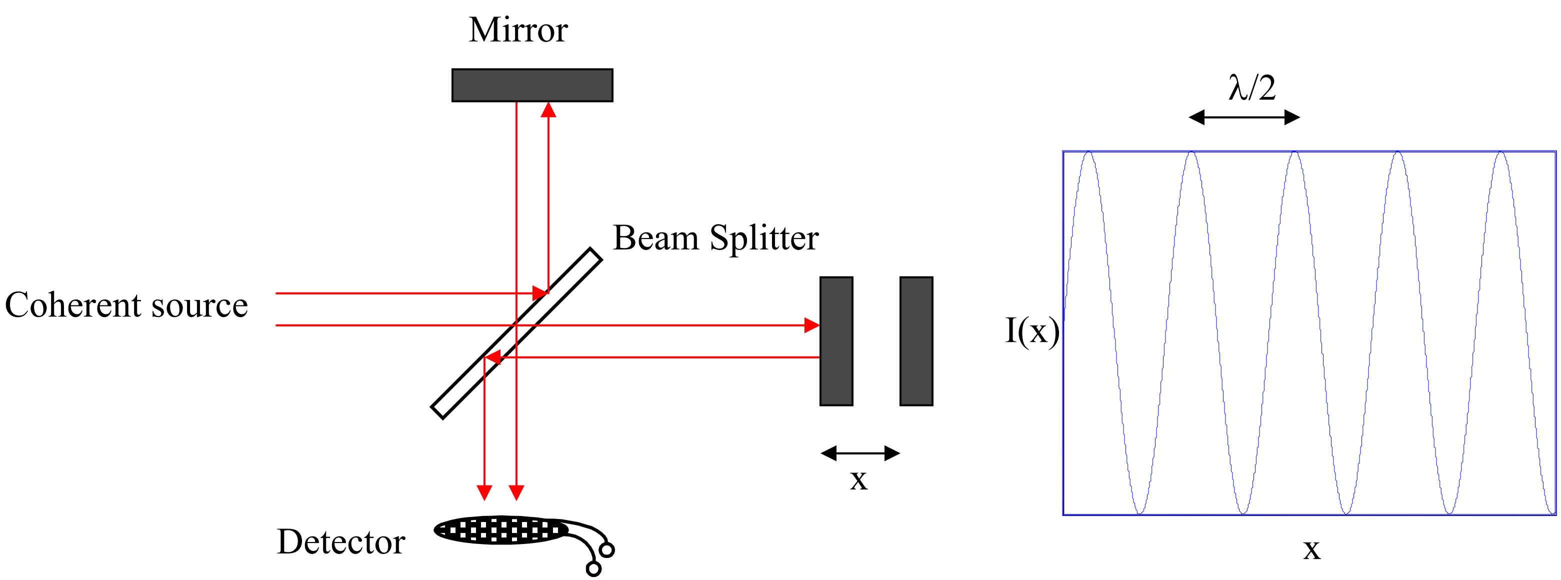
  (from The Commercialization of Microsystems 2001)

CONTACT/NONCONTACT GEOMETRY MEASUREMENT

- Contact Measurement
  - CMM, Mechanical profilometer, AFM
    - Slow. Deforms devices. No dynamic measurement
- Noncontact Measurement
  - Microscope
    - Needs large lens for high accuracy in depth. No dynamic measurement
  - Interferometer
    - Dynamic measurement. Slow (no parallel operation). Each unit is expensive

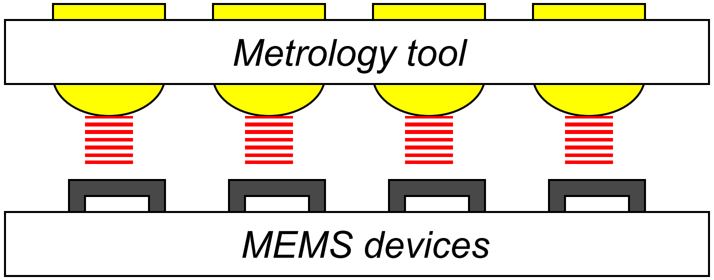
OPTICAL INTERFEROMETER

- Michelson's Interferometer
  - 10^{-4} Å/$\sqrt{Hz}$
  - Dynamic measurement: ~30MHz
  - Combines with lens for lateral resolution



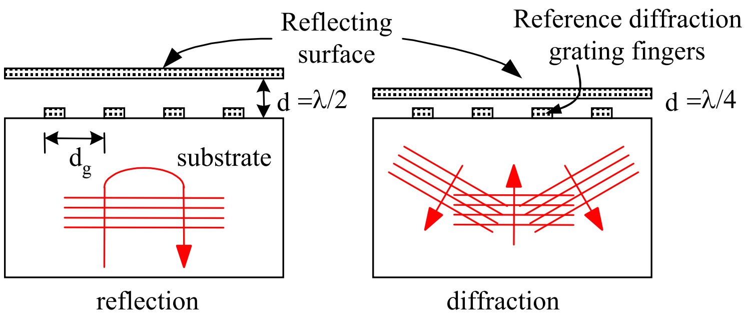
RESEARCH GOAL

- Metrology tool for MEMS
  - Needs small, fast, sensitive, parallel and inexpensive metrology tool
  - Noncontact measurement for dynamic structures $\Rightarrow$Interferometer
- Enabling technique for making small sensor
  - MEMS processing
  - Integration with electronics

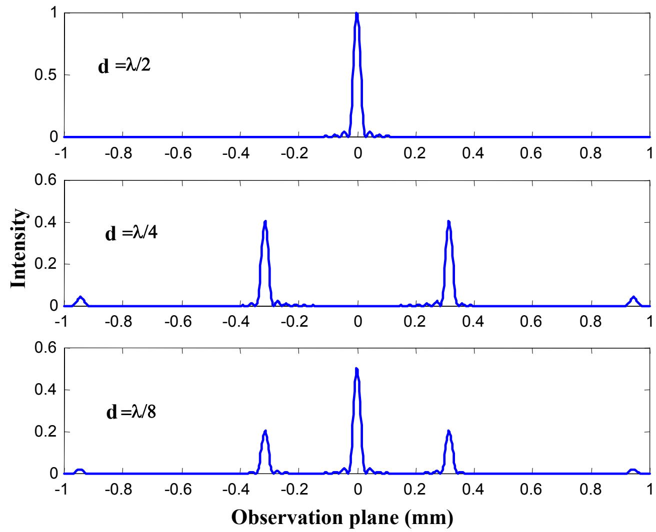


PHASE SENSITIVE DIFFRACTION BASED DISPLACEMENT DETECTION

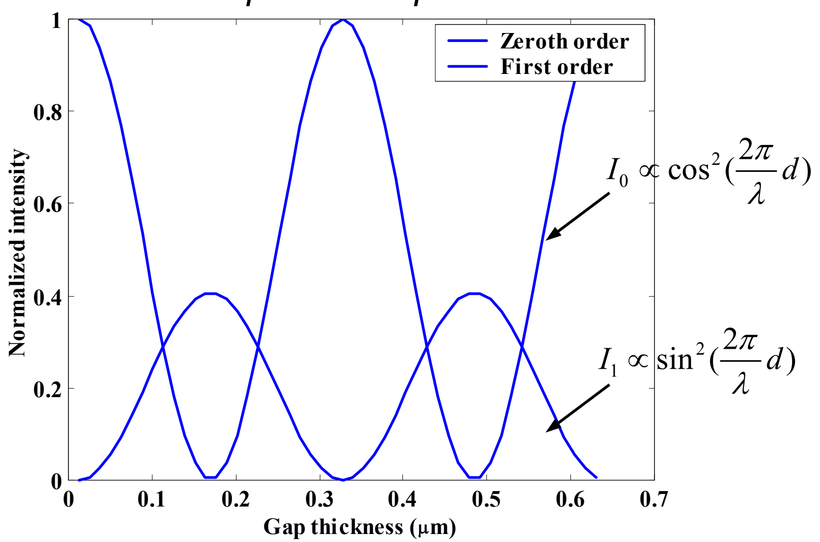
- Reflected mode intensity is periodic
- Interferometric precision can be achieved by monitoring the intensity of any of the reflected orders
- Example, HeNe laser (λ=632.8nm), 10 reference fingers with d_g=2μm



Diffraction pattern depends on d

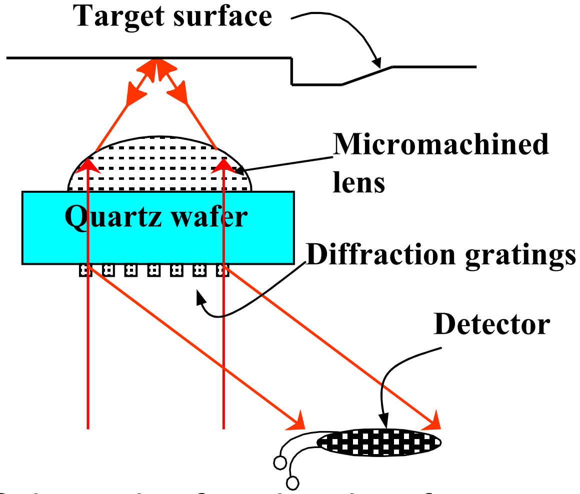


Distribution of the reflected light of the on an observation plane in simulation

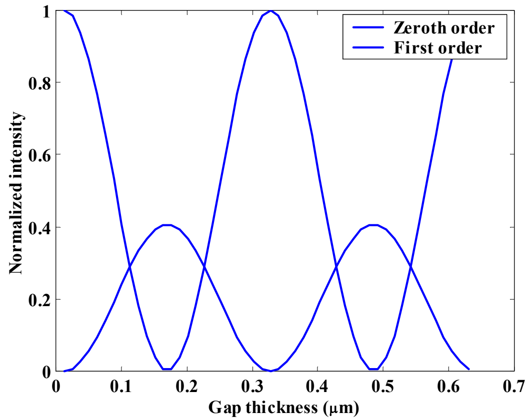


Variation of the intensity with distance d on an observation plane in simulation

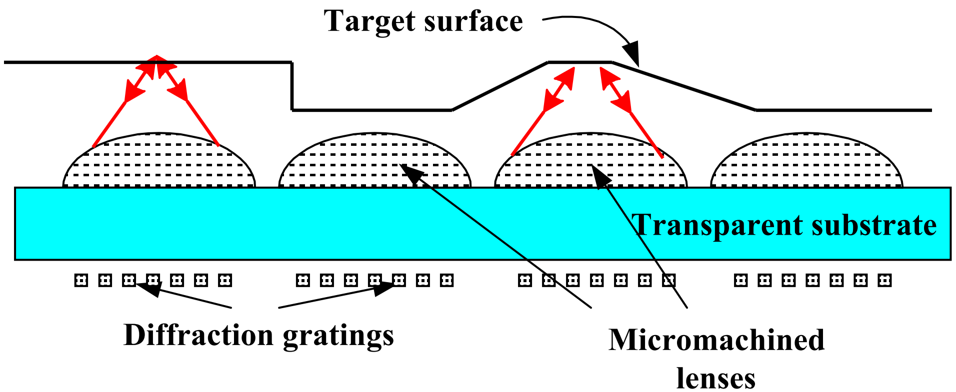
MICROINTERFEROMETER



Schematic of a micro-interferometer



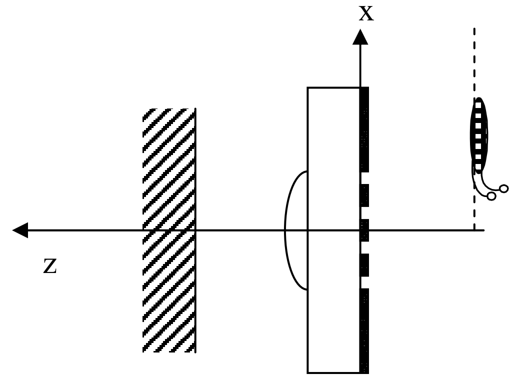
Variation of the intensity with distance d on an observation plane

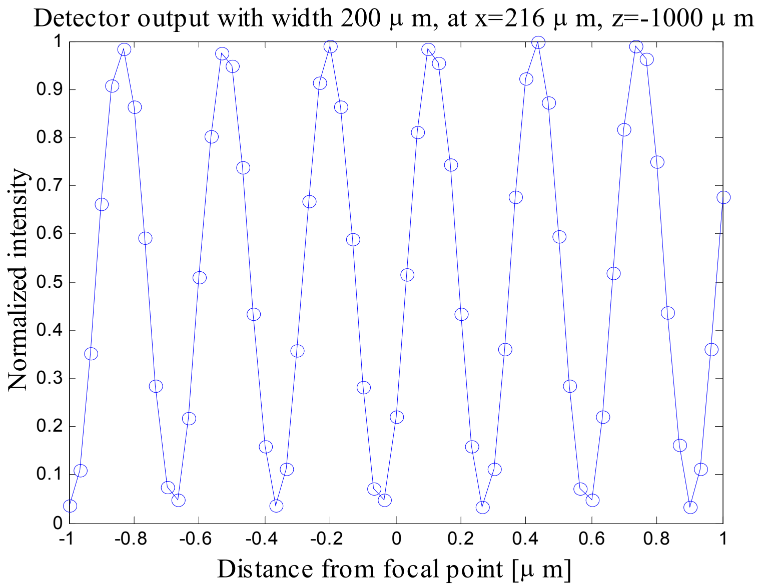


- Limitations
  - Not feasible to measure the step more than $\lambda/8$ change
  - Inclined angle should be less than $2\tan^{-1}(2\text{F-number})$

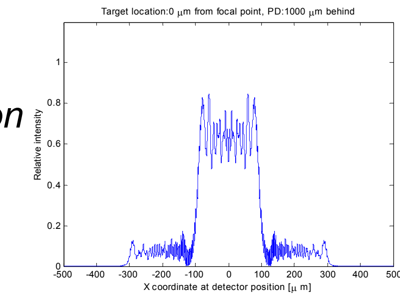
SYSTEM ANALYSIS (1D)

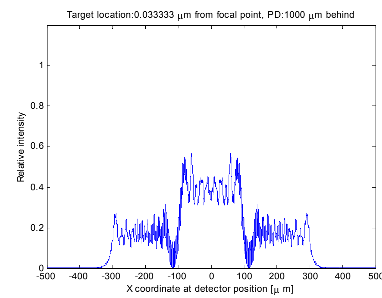
- Designed lens and 3 μm period diffraction grating having 1.5 μm blank
- 2[nd] lobe is seen around 216 μm {=1000tan[sin-1(0.6328/3)]}
- Photo detector having width 200μm at z=-1000 μm, x=216μm

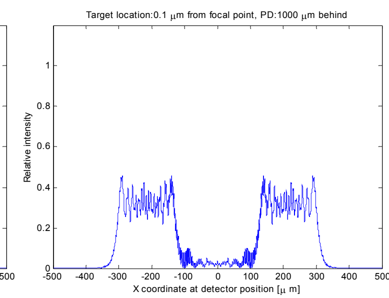




Intensity variation on the photo detector plane

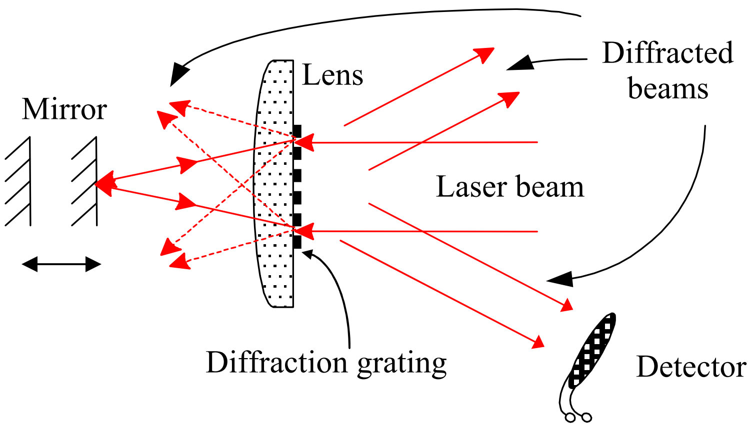


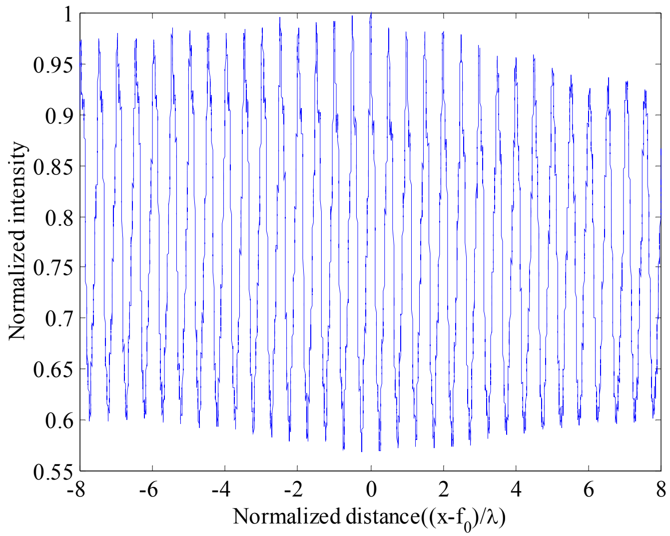




FEASIBILITY TEST OF SYSTEM

- Travel distance of $\lambda/2$ per one cycle. For HeNe laser (λ=632.8nm), it is about 0.3 μm

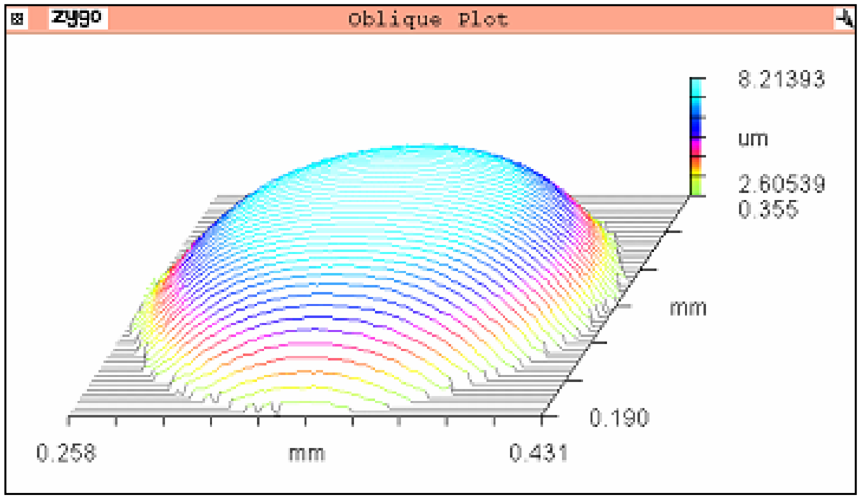


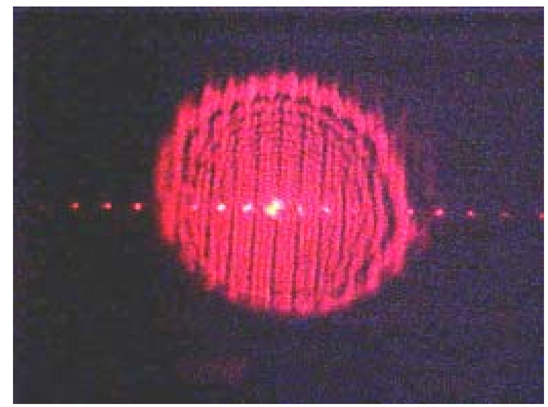


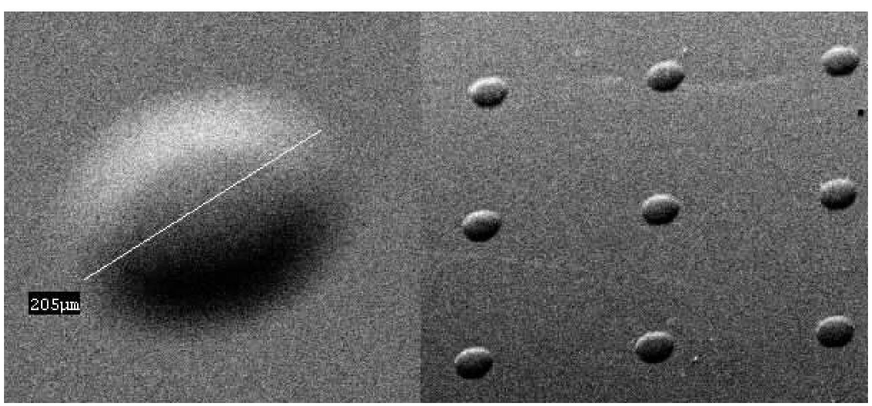
Measured diffraction intensity at the detector in normalized distance in experiment

FABRICATED LENS SAMPLE

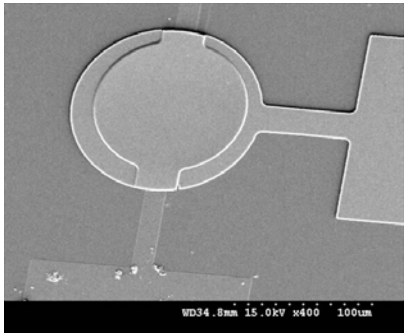
- Radius of curvature=612.1 μm, focal length=991 μm, maximum deviation from sphere=0.13%, power loss=30%



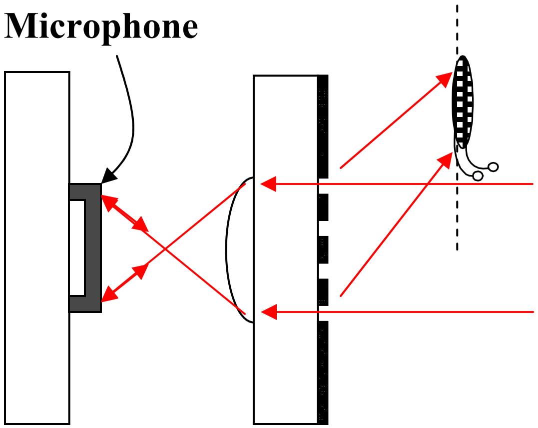


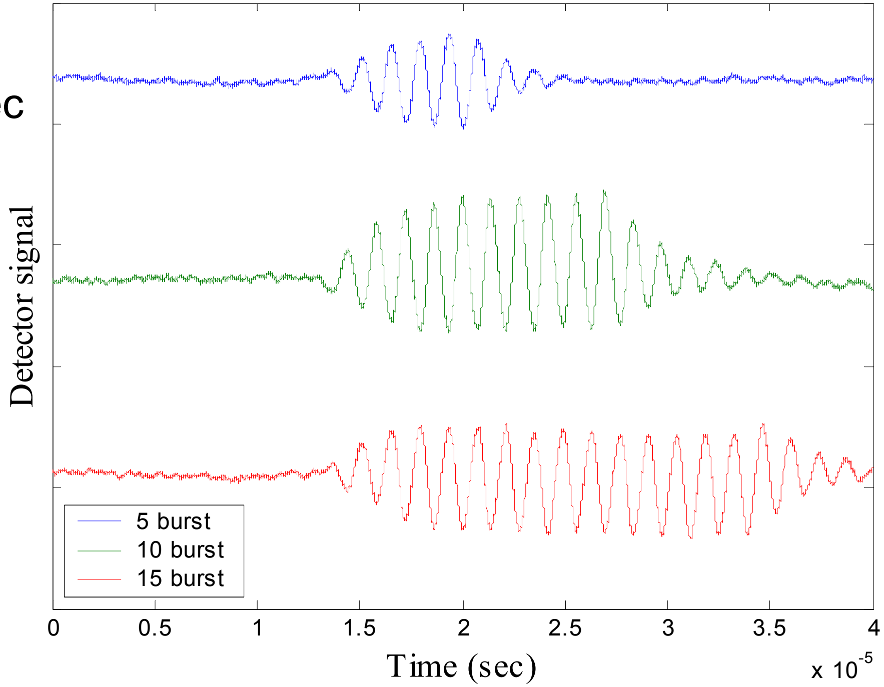


FREQUENCY MEASUREMENT OF MICROPHONE



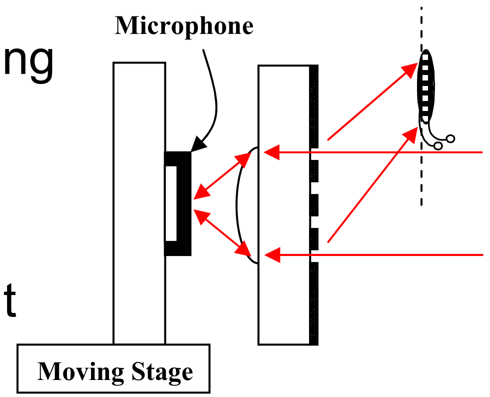
- MEMS Microphone
  - 160 μm diameter
  - Electrostatic actuated at 720kHz by 100V(DC)±16V(AC)
  - 5,10,15 burst
- Detector signal
  - 720kHz≈10cycles/1.39x10^{-5} sec
  - Shows ringing

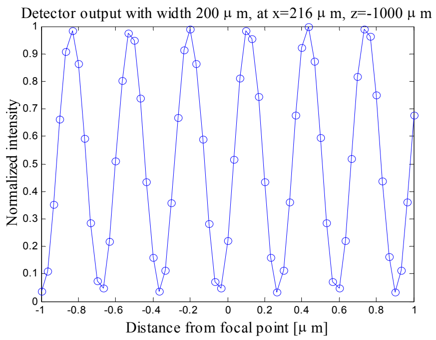


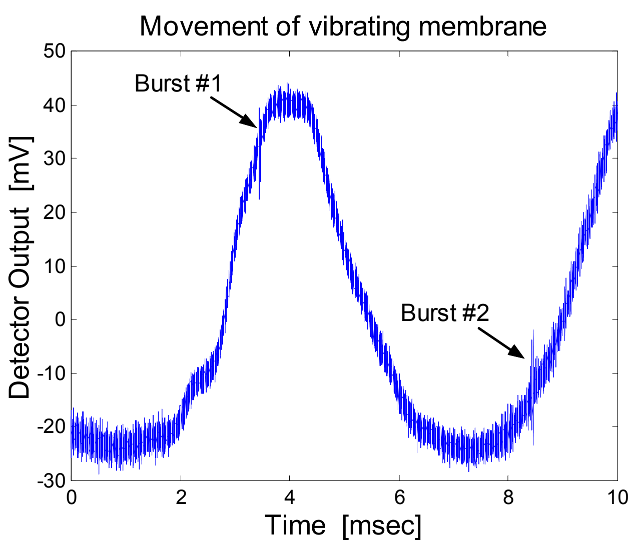


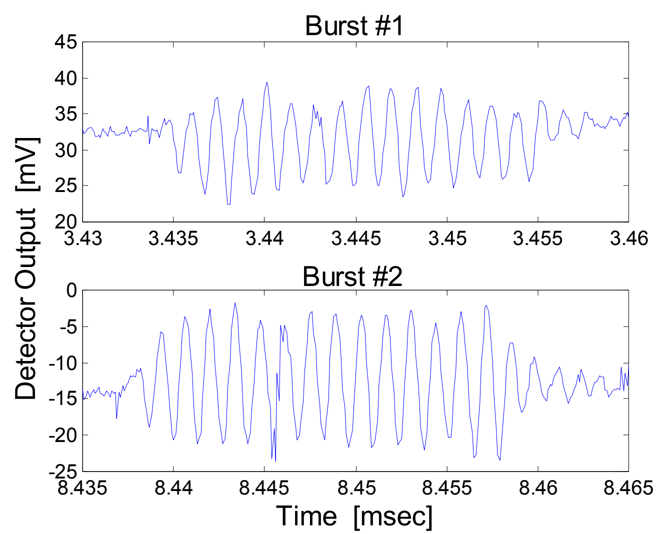
DISPLACEMENT MEASUREMENT OF MICROPHONE

- MEMS Microphone
  - Two times of 15 bursts during moving 50 μm/sec on the stage
  - λ/2 (≈ 0.3 μm) period
  - ±10~15 nm of displacement during bursts



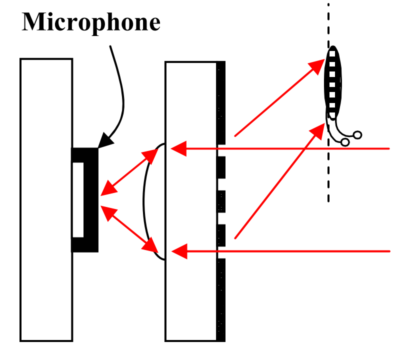


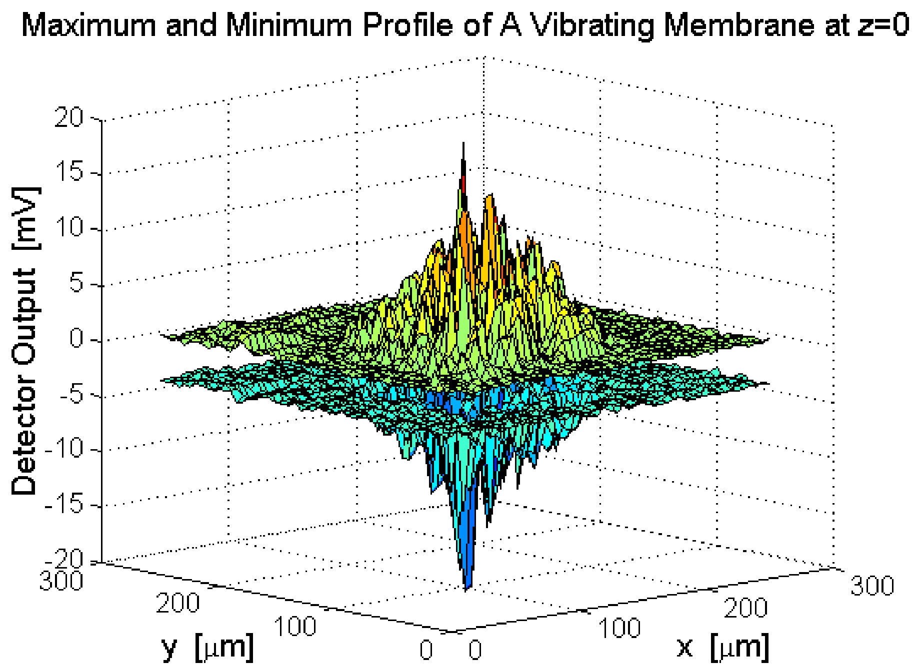


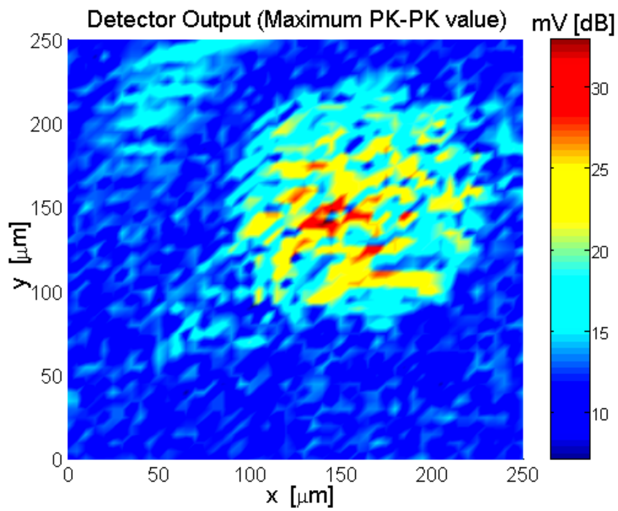


SCANNING OF MICROPHONE

- MEMS Microphone
  - 5 μm scanning step
  - Sensitive to alignment error

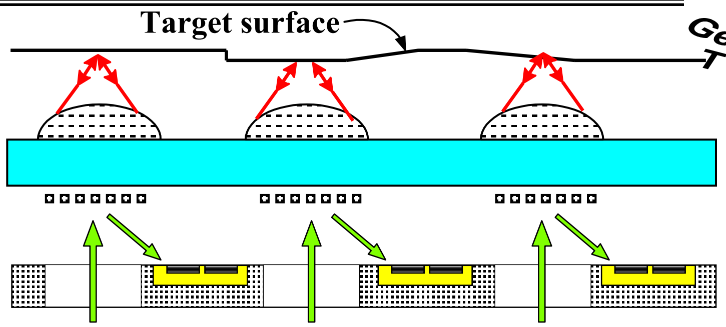


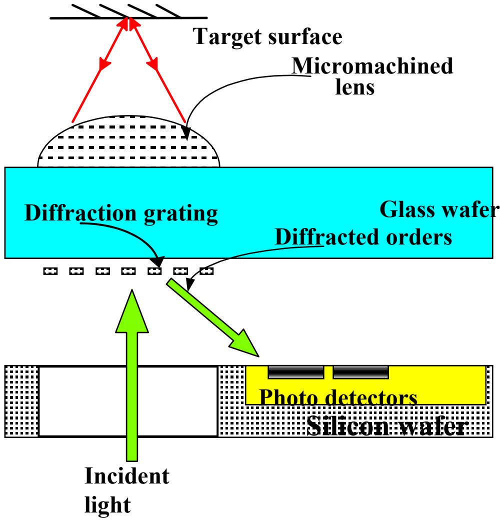


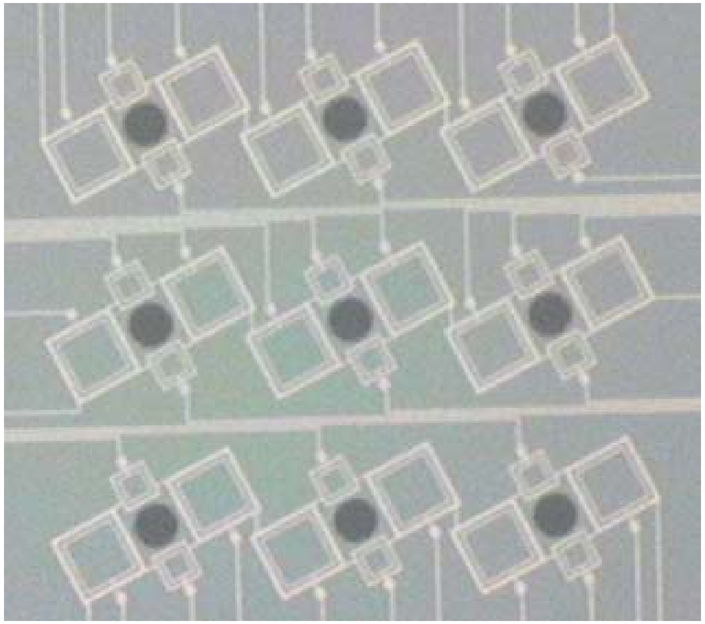


INTEGRATED SYSTEM

- Implementation of the proposed micro-inteferometer structure with integrated electronics
- Si PN-junction photodiode was fabricated to detect 1st order
- Trough-hole etch by ICP (Inductively Coupled Plasma) etcher







Fabricated photodiode

CONCLUSION

- Feasibility test results of the sensor show a good agreement with analysis results
- Fabricated micro lenses was characterized by surface measurement
- Vibrating frequency of the microphone can be detected using proposed sensor
- Vibration magnitude of the microphone is also detectable if the sensor is properly calibrated