courtesy of Prof. Urey

MEMS FTIR Spectrometer and Optical Results

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memfis

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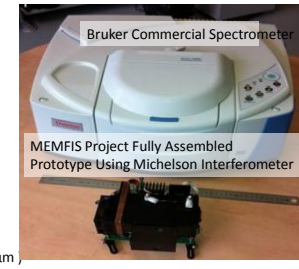
Fourier Transform Spectrometer (FTS) Motivation

- FTIR Spectrometers are used for:
  - Quality and process control
  - Gas detection
  - Chemical analysis etc.
- Currently available spectrometers
  - Bulky
  - High cost
  - Only for lab use
  - Low measuring speed
- MEMFIS Project Specs.:
  - Handheld
  - Fast measurement (1-2 msec)
  - Sensitive (10cm^{-1})
  - Works in midIR region (2.5µm -16µm)
  - Two Approaches:
    - Michelson Interferometer
    - Lamellar Grating Interferometer



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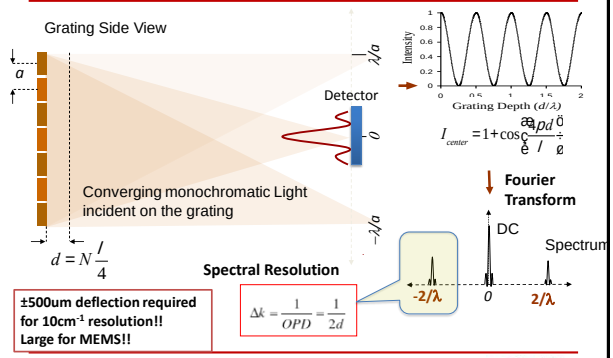
Lamellar Grating Interferometer Operation with Laser Illumination



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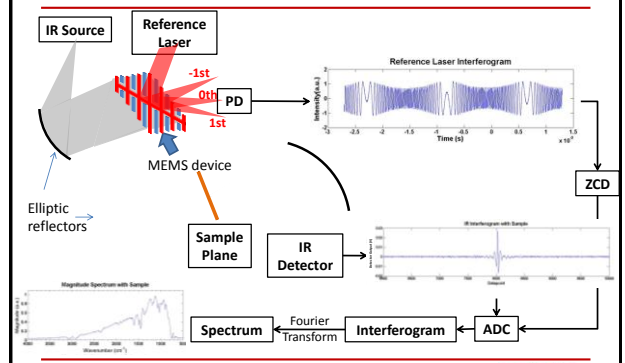
FTS with Lamellar Grating Interferometer (LGI)



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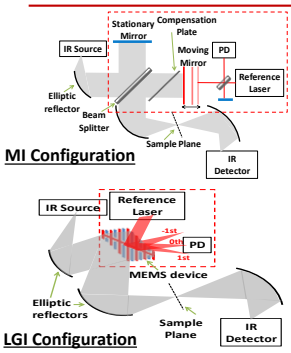
Michelson Interferometer vs LGI for FTS



Lamellar Grating Interferometer (LGI) Advantages over Michelson Interferometer:

- ✓ **LGI Eliminates**
  - ✓ reference mirror
  - ✓ beam splitter
  - ✓ compansation plate
  - ✓ interference alignment efforts
  - ✓ vacuum packaging of MEMS
- ✓ LGI is Achromatic
- ✓ LGI is less susceptible to vibration noise
- ✓ LGI is *smaller*, *more robust* and *easier to assemble*
- X *LGI useful range is limited by Talbot distance*

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O. Ferhanoglu et al., Optics Express, 2009.

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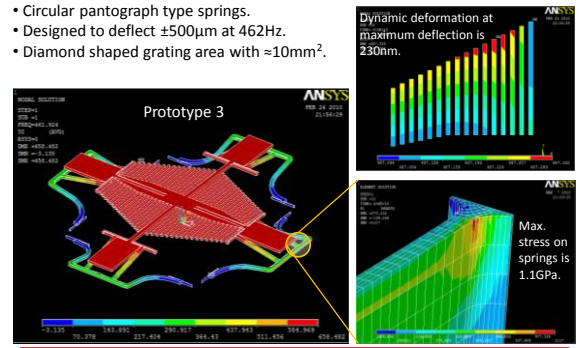
LGI Mechanical Design

- Circular pantograph type springs.
- Designed to deflect ±500µm at 462Hz.
- Diamond shaped grating area with ≈10mm^2.



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H. R. Seren et al, J. MEMS 2012

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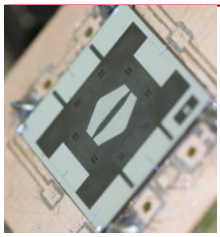
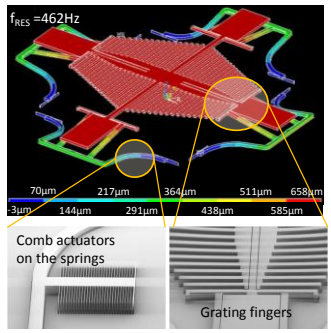
3rd Prototype Devices

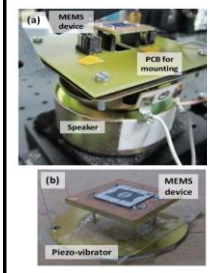


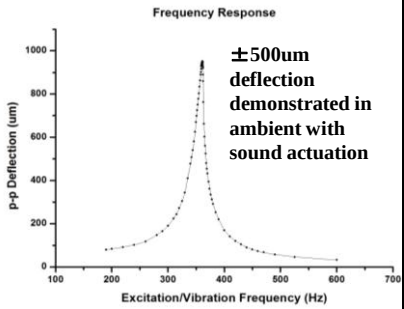


- Standard 4 mask SOI process
- 75μm device layer
- Al top reflector
- 11mm x 11mm die area

H. R. Seren et al, J. MEMS 2012

3 Different Actuation Methods: Comb drive, Speaker, and Piezo Vibrator

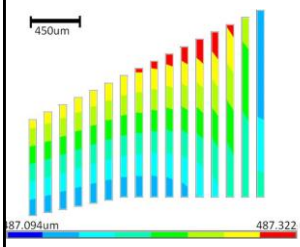




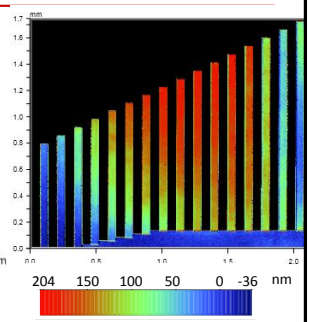
±500um deflection demonstrated in ambient with sound actuation

Seren et al, J. MEMS, 2012

Dynamic Finger Deformation Desired to be <λ/10

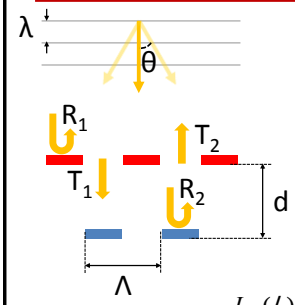


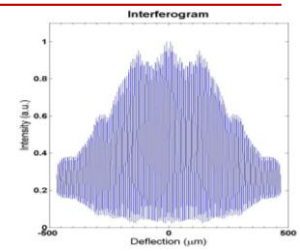
ANSYS Modeling of finger deformation at 975μm p-p deflection.
Max deformation: 228nm



Measurement by white light interferometry of finger deformation at 400μm p-p deflection (sound pressure actuation).
Max deformation: 240nm

Physical Optics Simulations

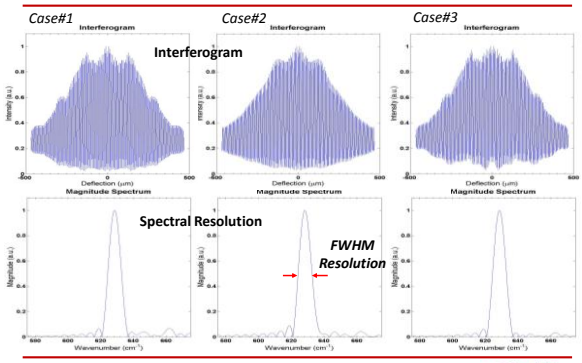




Interferogram

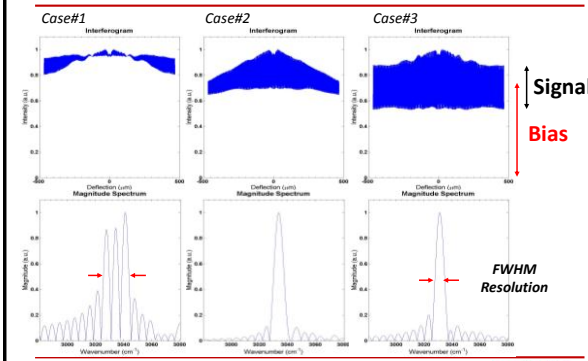
$$I_{det}(l) = \sum_{q} \sum_{d} FT\{I\{R_1\} + I\{T_1, R_2, T_2\}\}$$

Interferogram and Magnitude Spectrum for λ=16μm



All cases give the same SPECTRAL RESOLUTION for λ=16um

Interferogram and Magnitude Spectrum for λ=3.3μm

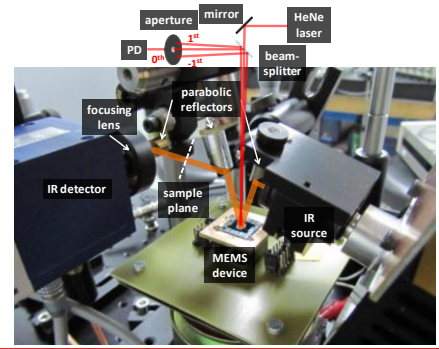


Case 13 is best for λ=3.3um

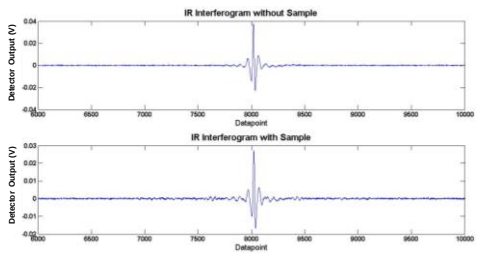
Physical Optics Simulation Results

	Spectral Resolution at different λ		
	3.3um	6.45um	16um
Case 1	36	12	17
Case 2	15	14	17
Case 3	13	12	17

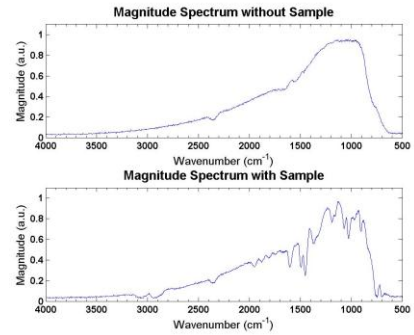
FTS System Operation



IR Interferogram with and without Polystyrene – *filtered and zoomed*



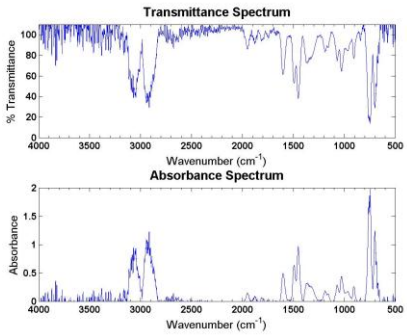
IR Spectra with and without Polystyrene



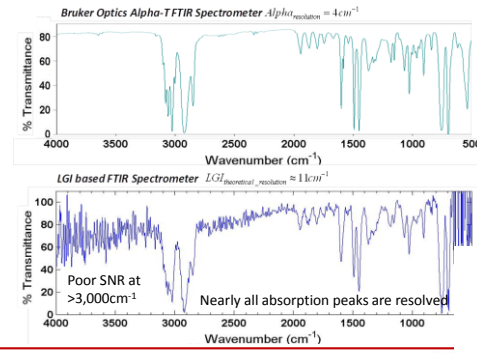
% Transmittance and Absorbance Spectra of Polystyrene

$$\%T = \frac{I}{I_0} * 100$$

$$A = -\log(\%T/100)$$



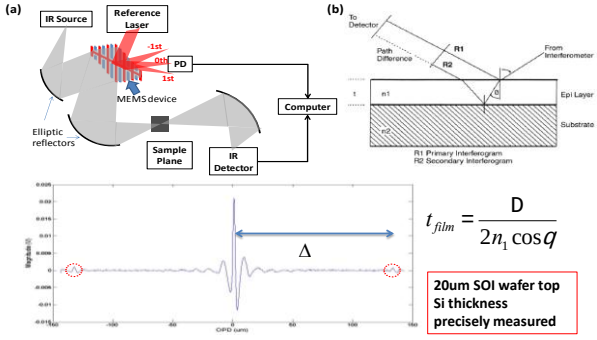
Transmission Spectra Comparison Commercial FTIR vs. Our FTIR



Spectral resolution of 20-30cm^{-1} achieved

Best MEMS-LGI performance reported

Application: Thin Film Thickness Measurement



$$t_{film} = \frac{D}{2n_1 \cos q}$$

20um SOI wafer top Si thickness precisely measured

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Summary

- LGI MEMS devices designed and fabricated
- Clear aperture size of 10mm2 and displacement up to ±500µm is achieved at 462Hz achieved
- A bench top LGI based FTIR spectrometer that works in mid-IR region (2.5-16µm) is built
- Optical design is optimized using Zemax, Physical Optics simulations, and confirmed with experimental results. Longer focal length lens combinations worked the best.
- A resolution of 25-30cm^{-1} is obtained in a broadband spectrum.
- Film thickness for a 20µm Silicon Layer in an SOI wafer is successfully measured with precision.

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