
MULTICHANNEL MEMS SPECTROMETER

University of California at Los Angeles
Department of Mechanical Engineering
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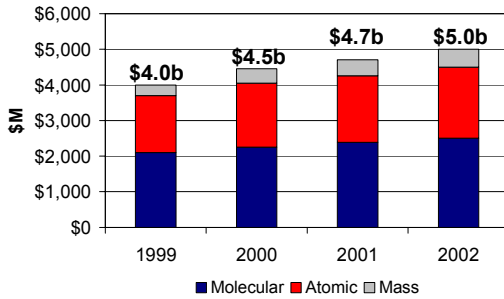
Alejandro Covalin, Willem-Jan Ouborg, Gary Lee

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3. Principles of Spectroscopy
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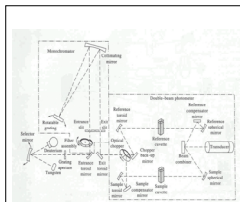
Spectroscopy Market

WORLDWIDE SPECTROSCOPY MARKET

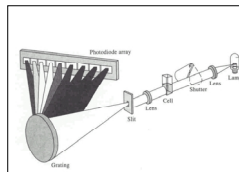


- In 2001, the molecular spectroscopy segment will generate \$2.2b in shipment revenues.
- UV/Visible/IR products represent over a third of the molecular spectroscopy segment.

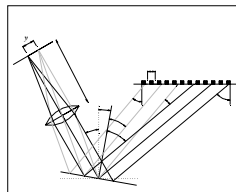
Product Comparison



Double Beam



Multichannel Diode Array



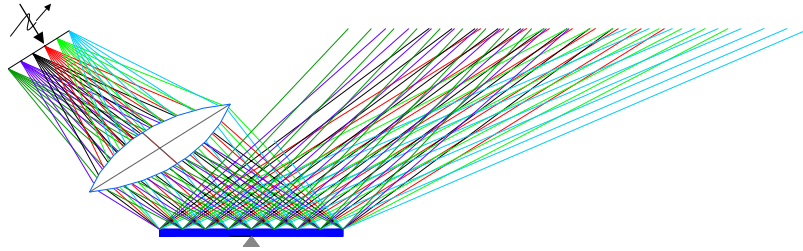
MEMS Spectrometer

Cost	\$4,000 to \$15,000	\$7,000 to \$9,000	<\$1,000
Resolution	4 nm	2 nm	<0.5 nm
Spectrum	190 to 850 nm (UV/Visible)	Up to 850 nm (UV/Visible)	100 to 1100 nm (UV/Visible/IR)
Scanning Speed	N/A	Very Fast ⁽¹⁾	Fast

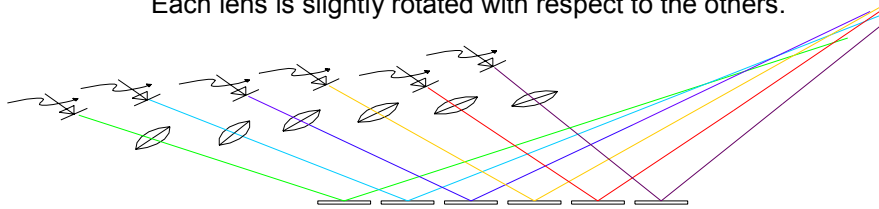
⁽¹⁾ Multiple scans are performed

Principles of Spectroscopy

The photodiode is placed at the focal point.



Each lens is slightly rotated with respect to the others.

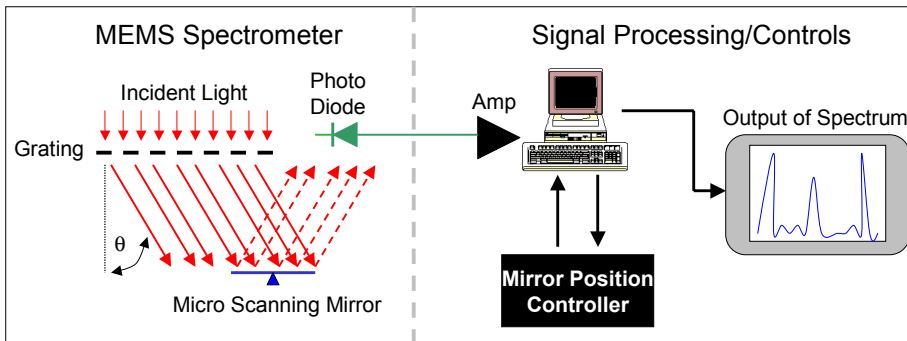


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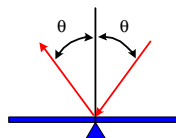


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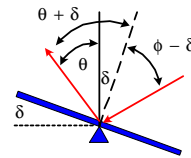
Product Overview



Grating Equation:
 $d \cdot \sin \theta = \lambda \cdot m \quad m = 0, \pm 1, \pm 2, \dots$
 d – distance between grating rulings



$$\theta + \delta = \phi - \delta \Rightarrow \delta = \frac{\phi - \theta}{2}$$



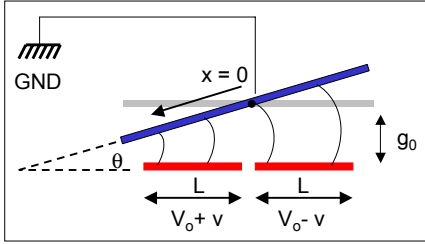
$$g = R \cdot \theta = \left(\frac{d}{\sin \theta} - x \right) \cdot \theta$$

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Torsion Mirror Analysis



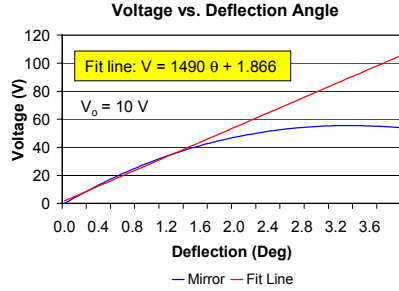
$$(1) T_{elec} = \frac{1}{2} \frac{\epsilon_o A V^2}{g^2}$$

$$(2) V^2 = (V_o + v)^2 - (V_o - v)^2 = 4 \cdot V_o \cdot v$$

$$(3) \frac{1}{g^2} = \int_0^L \frac{1}{\left(\frac{d}{\sin \theta} - x\right)^2} dx$$

$$(4) T_{mech} = \frac{G \cdot J}{L} \theta = \frac{1}{C_M} \theta$$

$$(5) v = \frac{\theta}{2 \cdot \epsilon_o V_o W C_M} \int_0^L \frac{x}{\left(\frac{d}{\sin \theta} - x\right)^2} dx$$



- The Push-Pull Mirror provides a more linear slope, thus makes it easier to scan angles; analog not digital system.

Pull-in Voltage:

$$V_{pull-in} = \sqrt{\frac{2 \cdot d^3}{\epsilon_o W L^2 C_M}}$$

Pull-in = 47.5V or 2 deg

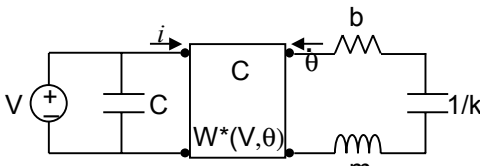
Source: Hiroshi Toshiyoshi

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Lumped Element Diagram



$$W = \frac{1}{2} C V^2$$

$$C = C_0 + a_1 \theta + a_2 \theta^2 + a_3 \theta^3$$

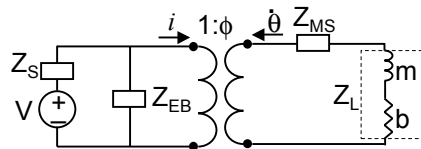
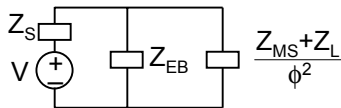
$$a_1 = 4.15 \times 10^{-14}$$

$$t_{ele} = \frac{dW}{d\theta} = \frac{V^2 C}{2} (a_1 + 2a_2 \theta + 3a_3 \theta^2)$$

$$a_2 = 2.93 \times 10^{-13}$$

$$a_3 = 2.33 \times 10^{-12}$$

$$t_{mec} = l \dot{\theta} + b \theta + k \theta$$



$$W = \frac{Q^2}{2C} = \frac{Q^2}{2C_o} \left(\frac{1}{a_0 + a_1 \theta^2 + a_2 \theta^3} \right) = \frac{Q^2}{2C_o P(\theta)}$$

$$\tau = \frac{\partial W}{\partial \theta} \Big|_Q; \quad V = \frac{Q}{C_o P(\theta)}$$

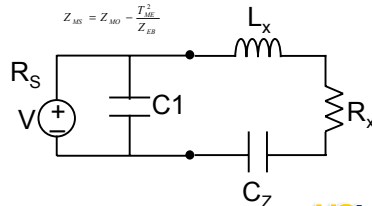
$$\begin{bmatrix} \delta V \\ \delta \tau \end{bmatrix} = \begin{bmatrix} Z_{EB} & T_{EM} \\ T_{ME} & Z_{MO} \end{bmatrix} \begin{bmatrix} \delta i \\ \delta \theta \end{bmatrix} = \begin{bmatrix} Z_{EB} & \Phi Z_{EB} \\ \Phi Z_{EB} & Z_{MO} \end{bmatrix} \begin{bmatrix} \delta i \\ \delta \theta \end{bmatrix}$$

$$Z_{EB} = \frac{2}{s C_o P(\theta)}; \quad T_{EM} = T_{ME} = -\frac{\Delta Q P'(\theta)}{s C_o P^2(\theta)}$$

$$Z_{MO} = \frac{(Q^2 - Q_o^2)}{2 s C_o} \left(\frac{P'(\theta)}{P^2(\theta)} - \frac{P''(\theta)}{P^3(\theta)} \right) + k$$

$$\Phi = \frac{T_{EM}}{Z_{EB}}$$

$$Z_{MS} = Z_{MO} - \frac{T_{ME}^2}{Z_{EB}}$$

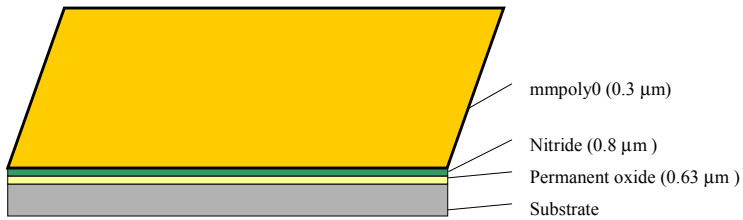


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SUMMiT Process

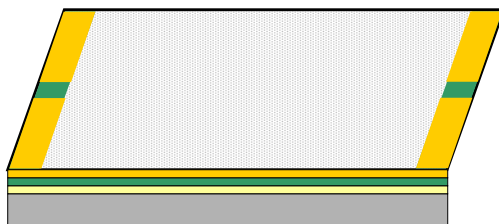
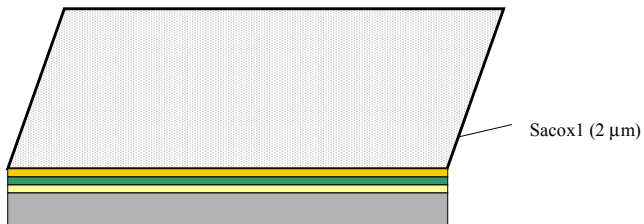


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SUMMiT Process (Cont'd)

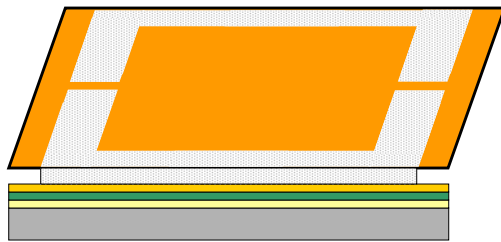
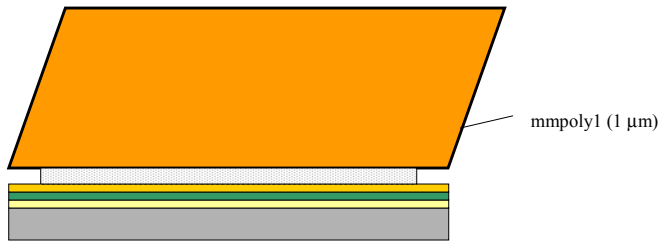


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SUMMiT Process (Cont'd)

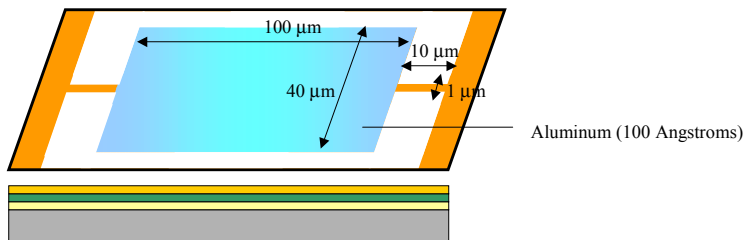


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SUMMiT Process (Cont'd)



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QUESTIONS

