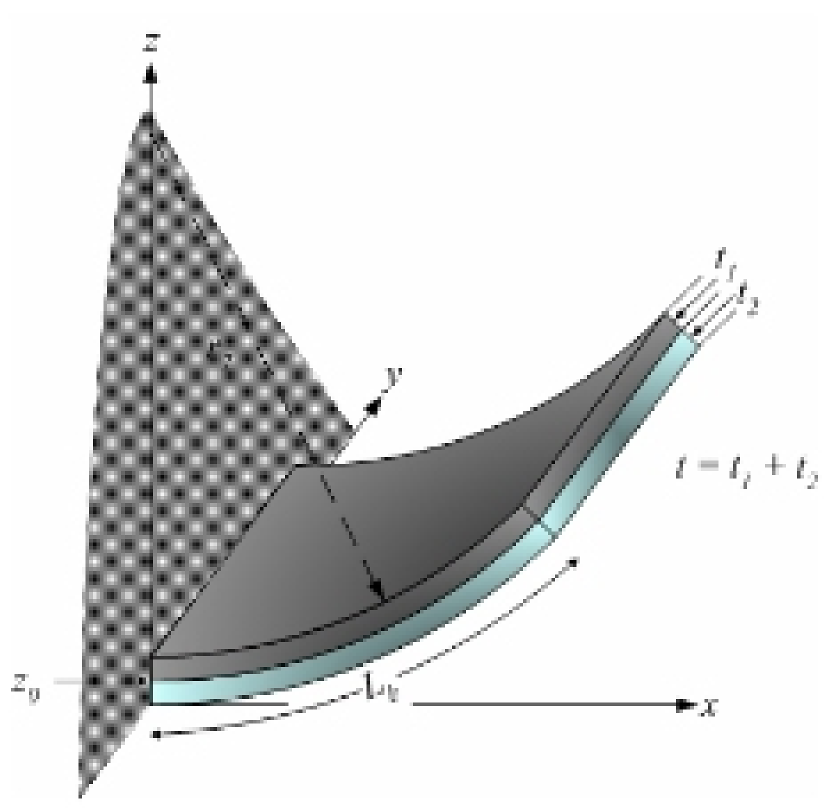
Lecture 21
Optical MEMS (3)

- Agenda:
  - Micromirrors
    - Thermal Actuation
      - Bimorph
      - Hot-arm
      - Lateral

Bimorph Actuator Design



ΔT: temperature change.
α_1: temperature coefficient of expansion of first layer
α_2: temperature coefficient of expansion of second layer
E_1: Young's modulus of first layer
E_2: Young's modulus of second layer

Strain due to temperature change:

$$\begin{cases} \varepsilon_{T1} = \alpha_1 \Delta T \\ \varepsilon_{T2} = \alpha_2 \Delta T \end{cases}$$

Corresponding stress:

$$\begin{cases} \sigma_{T1} = E_1 \varepsilon_{T1} = E_1 \alpha_1 \Delta T \\ \sigma_{T2} = E_2 \varepsilon_{T2} = E_2 \alpha_2 \Delta T \end{cases}$$

Bimorph Actuator Design

- The deformation of the beam due to ΔT causes bending strain inside the beam and the strain varies along the z-axis.
- Assume the mean strain is ε_0, and the plane of the mean strain is located at z_0.
- The **bending strain** can be written as

$$\varepsilon_b(z) = \varepsilon_0 + \frac{z_0 - z}{r} = \left(\varepsilon_0 + \frac{z_0}{r}\right) - \frac{z}{r}$$

where r is the radius of curvature, and z is the distance to the bottom of the beam. The **equivalent bending stress** is

$$\sigma_b(z) = E(z)\cdot\varepsilon_b(z)$$

$$E(z) = \begin{cases} E_1 & 0 \le z < t_1 \\ E_2 & t_1 \le z \le t_2 \end{cases}$$

Bimorph Actuator Design

At **equilibrium**, both the total force and the total bending moment should be equal to zero

$$\begin{cases} \sum F = \int_0^t \int_0^w \sigma(z)\,dydz = 0 \\ \sum M = \int_0^t \int_0^w \sigma(z)\,zdydz = 0 \end{cases}$$

where

$$\sigma(z) = \sigma_T(z) - \sigma_b(z)$$

$$\sigma_T(z) = \begin{cases} \sigma_{T1} & 0 \le z < t_1 \\ \sigma_{T2} & t_1 \le z \le t_1 + t_2 \end{cases}$$

Bimorph Actuator Design

Assuming the temperature and stress are uniform along the y axis, the **radius of curvature** due to temperature change, r_T, can be obtained by solving the force and moment equations:

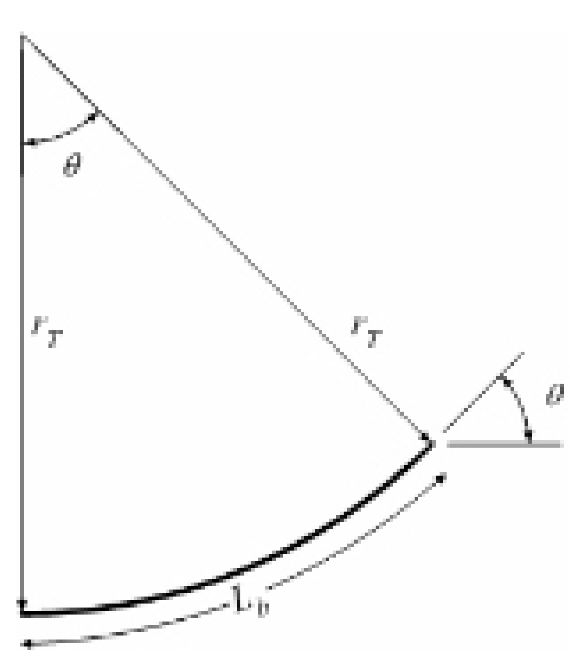
$$\frac{1}{r_T} = \frac{6t\left(\alpha_2 - \alpha_1\right)\Delta T}{4t_1^2 + 4t_2^2 + 6t_1t_2 + \dfrac{E_1t_1^3}{E_2t_2} + \dfrac{E_2t_2^3}{E_1t_1}}$$

$$\frac{1}{r_T} = \beta_r \Delta\alpha_T \Delta T$$

$\Delta\alpha_T = \alpha_2 - \alpha_1$ and β_r is **curvature coefficient**

$$\beta_r \triangleq \frac{6t}{4t_1^2 + 4t_2^2 + 6t_1t_2 + \dfrac{E_1t_1^3}{E_2t_2} + \dfrac{E_2t_2^3}{E_1t_1}}$$

Bimorph Actuator Design



Tangential angle at the beam end is given by

$$\theta = \frac{L_b}{r_T}$$

Substituting the expression for r_T yields

$$\theta\left(\Delta T\right) = \beta_r L_b \Delta\alpha_T \Delta T$$

We can define bimorph actuation sensitivity γ

$$\gamma = \theta / \Delta T = \beta_r L_b \Delta\alpha_T$$