

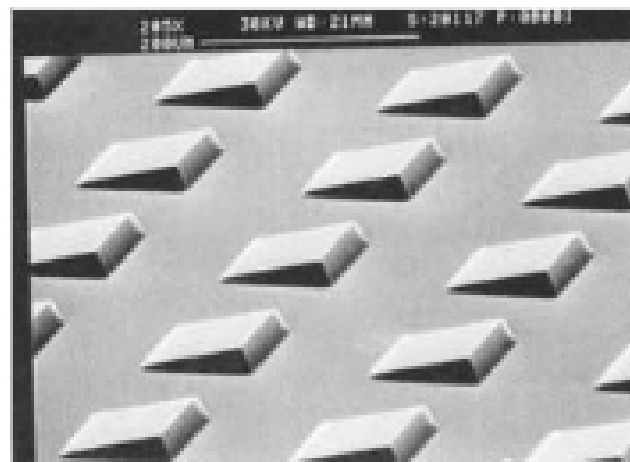
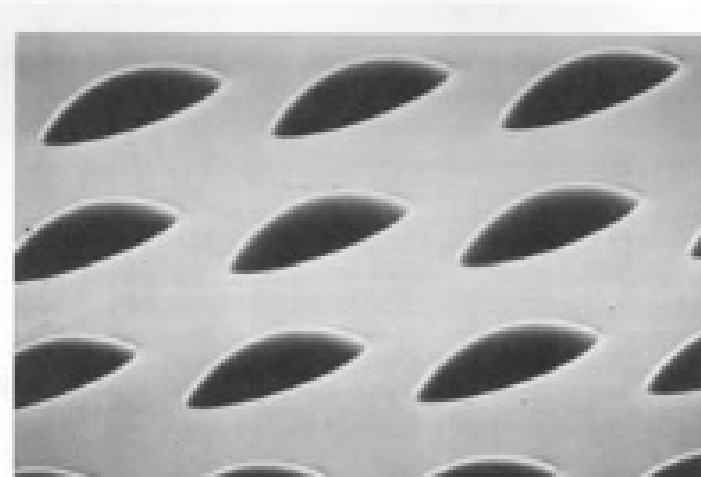
Lecture 23

Optical MEMS (5)

- Agenda:
 - Microlenses
 - Diffractive
 - Microgratings
 - Example Devices

Reference: S. Sinzinger and J. Jahns, Chapter 6 in *Microoptics*, Wiley-VCH, 2003

- Refractive optical elements require considerable thickness.
- For example, microlenses need 10~100 μm -thick microstructures.
- Even more challenging if aspherical lenses or complex phase profiles are needed.



- But we know that a light wave repeats itself after any multiple wavelengths or a phase lag of multiple 2π .

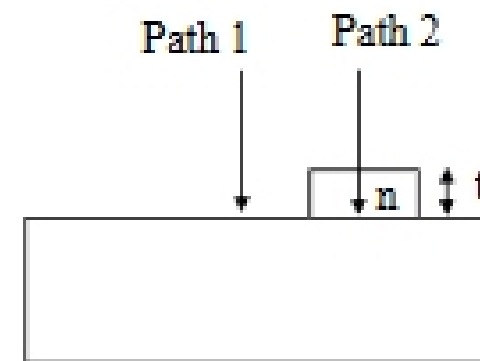
$$U(x, \phi) = U_0(x)e^{i\phi} = U_0(x)e^{i(\phi+2N\pi)}$$

Thus, only a maximum phase lag of 2π is necessary.

The phase difference between path 1 and path 2 is given by

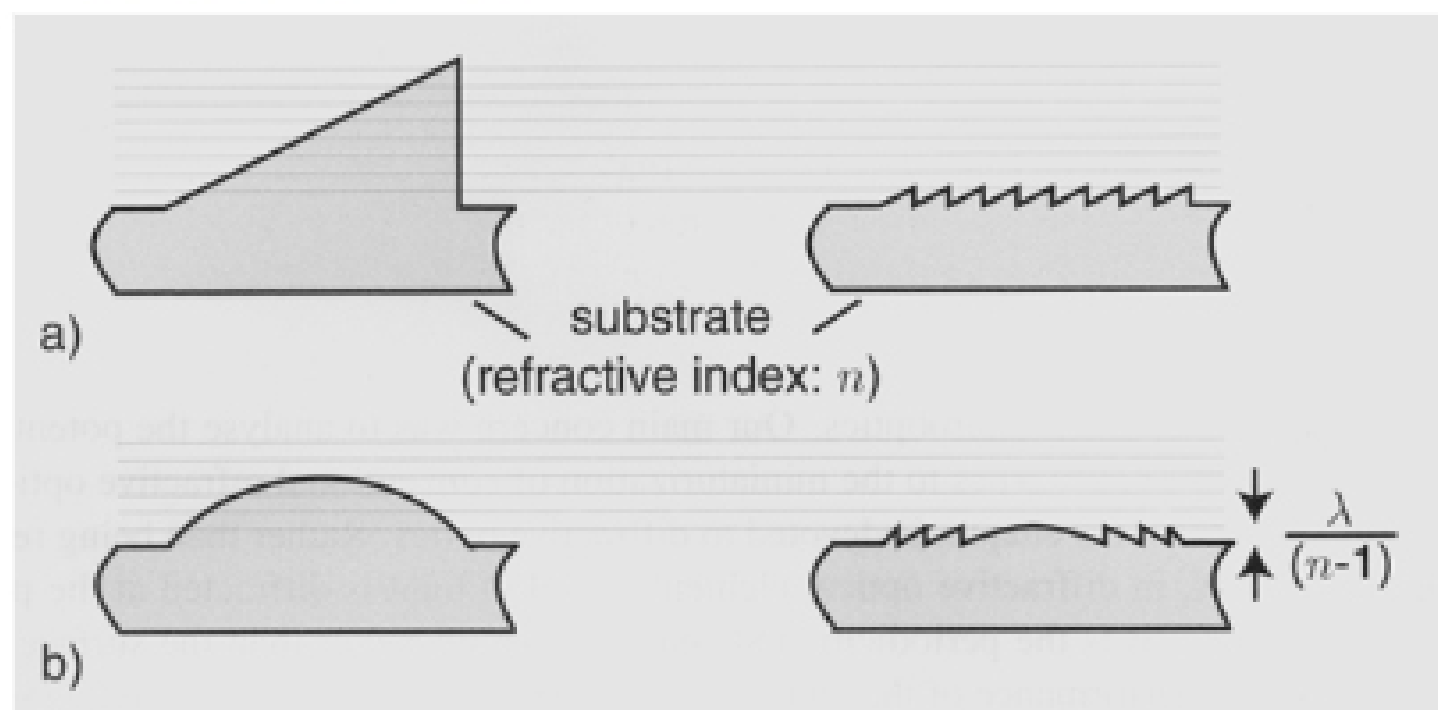
$$\Delta\phi = (nt - t) \frac{2\pi}{\lambda_0}$$

$$\Rightarrow t_{\max} = \frac{\lambda_0}{(n-1)}$$



For example, for $\lambda_0=633\text{nm}$ and $n=1.5$, the thickness needed is only $1.27\mu\text{m}$.

Therefore, the thickness of a prism or lens can be significantly reduced.



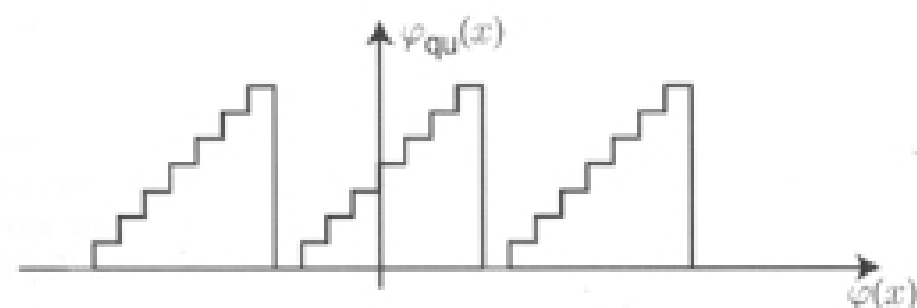
High lateral resolution is required, which is in fact photolithography can provide.

Step 1

Continuous phase \rightarrow mapping of the phase into $[0, 2\pi]$ periodically

Step 2

Continuous phase in each interval $[0, 2\pi] \rightarrow$ an integer number of discrete values



$$e^{i\phi_Q(x)} = \sum_{q=-\infty}^{q=+\infty} e^{iq \frac{2\pi}{N} \text{rect}\left[\frac{\phi(x)}{2\pi/N} - q\right]} \quad (1)$$

The **rect** function can be expanded into a Fourier series

$$\text{rect}\left[\frac{\phi(x)}{2\pi/N} - q\right] = \sum_{J=-\infty}^{+\infty} \left[\frac{\text{sinc}(J/N)}{N} e^{2\pi i(J/N)q} e^{iJ\phi(x)} \right] \quad (2)$$

Substituting (2) into (1) yields

$$\begin{aligned} e^{i\phi_Q(x)} &= \sum_m \left[\text{sinc}\left(m + \frac{1}{N}\right) e^{i(Nm+1)\phi(x)} \right] \\ &= \text{sinc}\left(\frac{1}{N}\right) \sum_{m=-\infty}^{+\infty} \left[\frac{(-1)^m e^{i(Nm+1)\phi(x)}}{Nm+1} \right] \end{aligned}$$