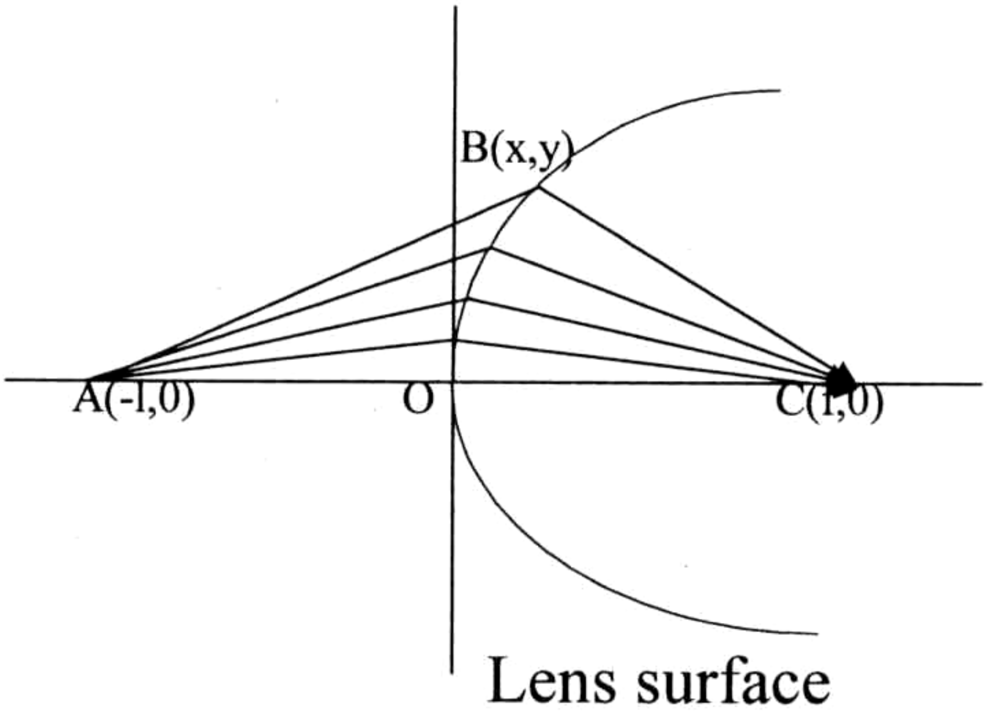
Fresnel Zone Plate

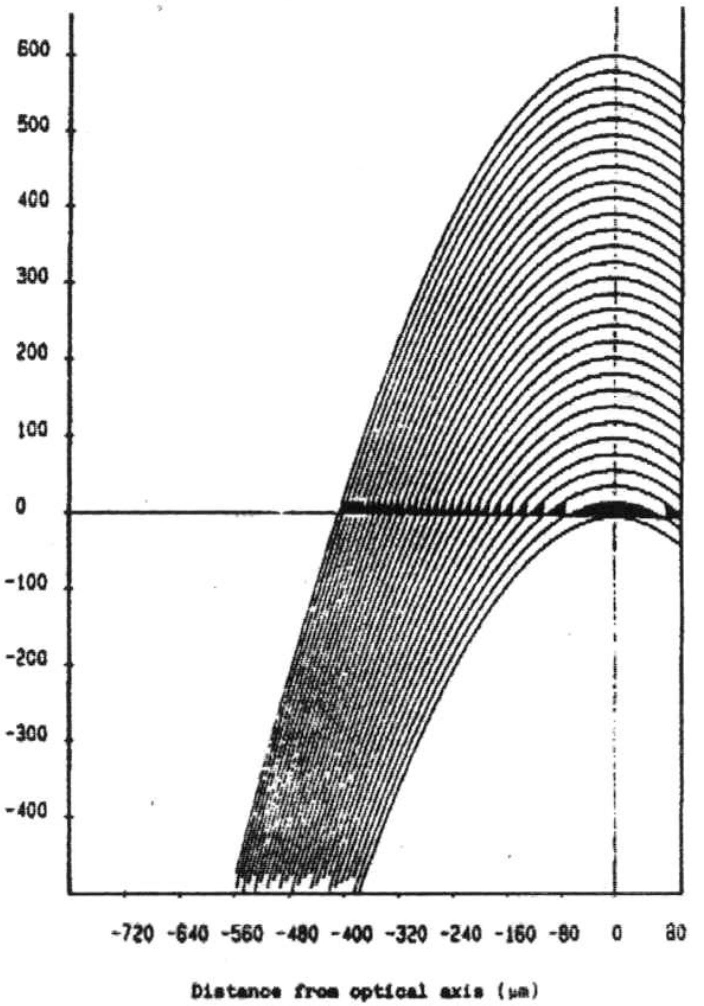
$$f(x,y)=\begin{cases}1, & \text{if } \cos\left(\pi\dfrac{x^2+y^2}{\lambda f}\right)>0\\ 0, & \text{otherwise}\end{cases}$$

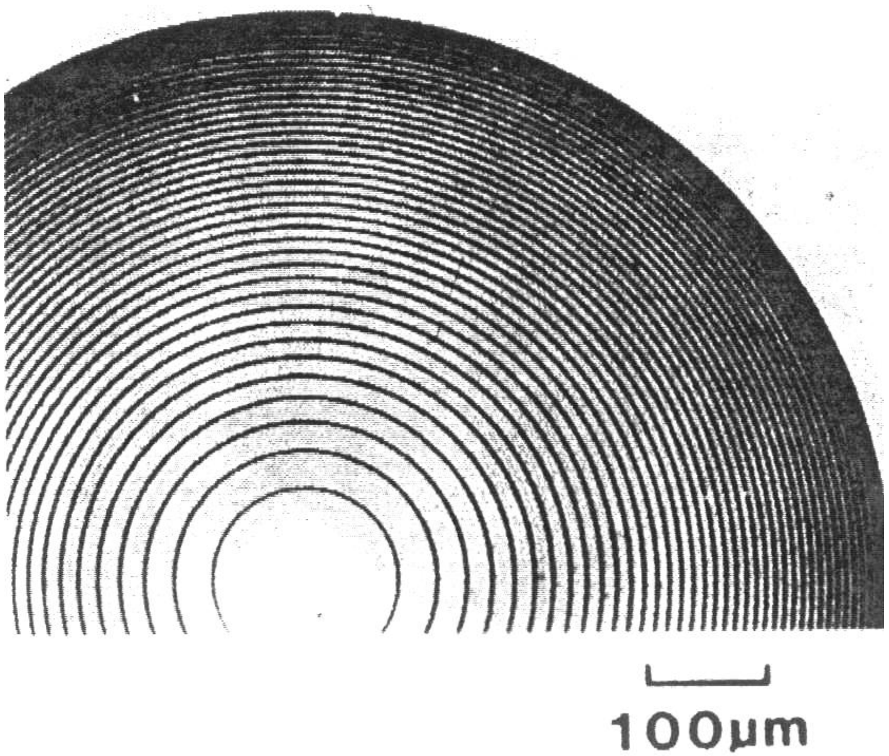
Lens design based on ray optics – equality of optical path length



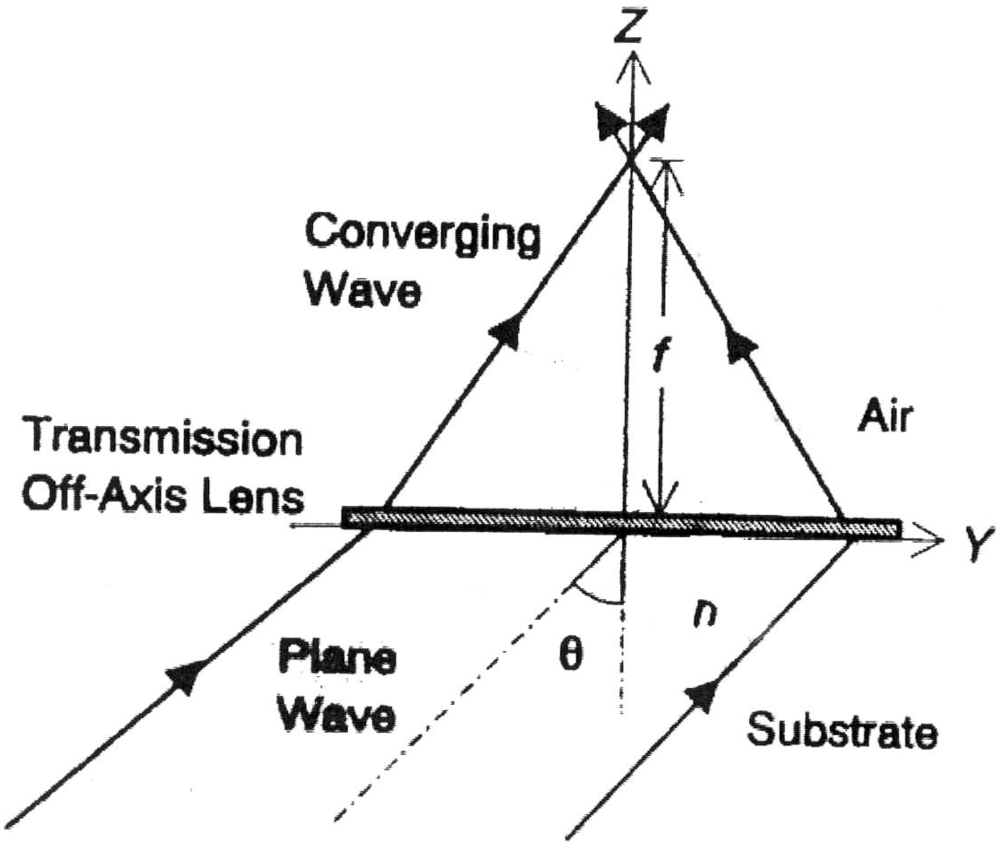
- The Optical paths should be the same to be focused on one spot (refractive index should be considered).

Fresnel Lens

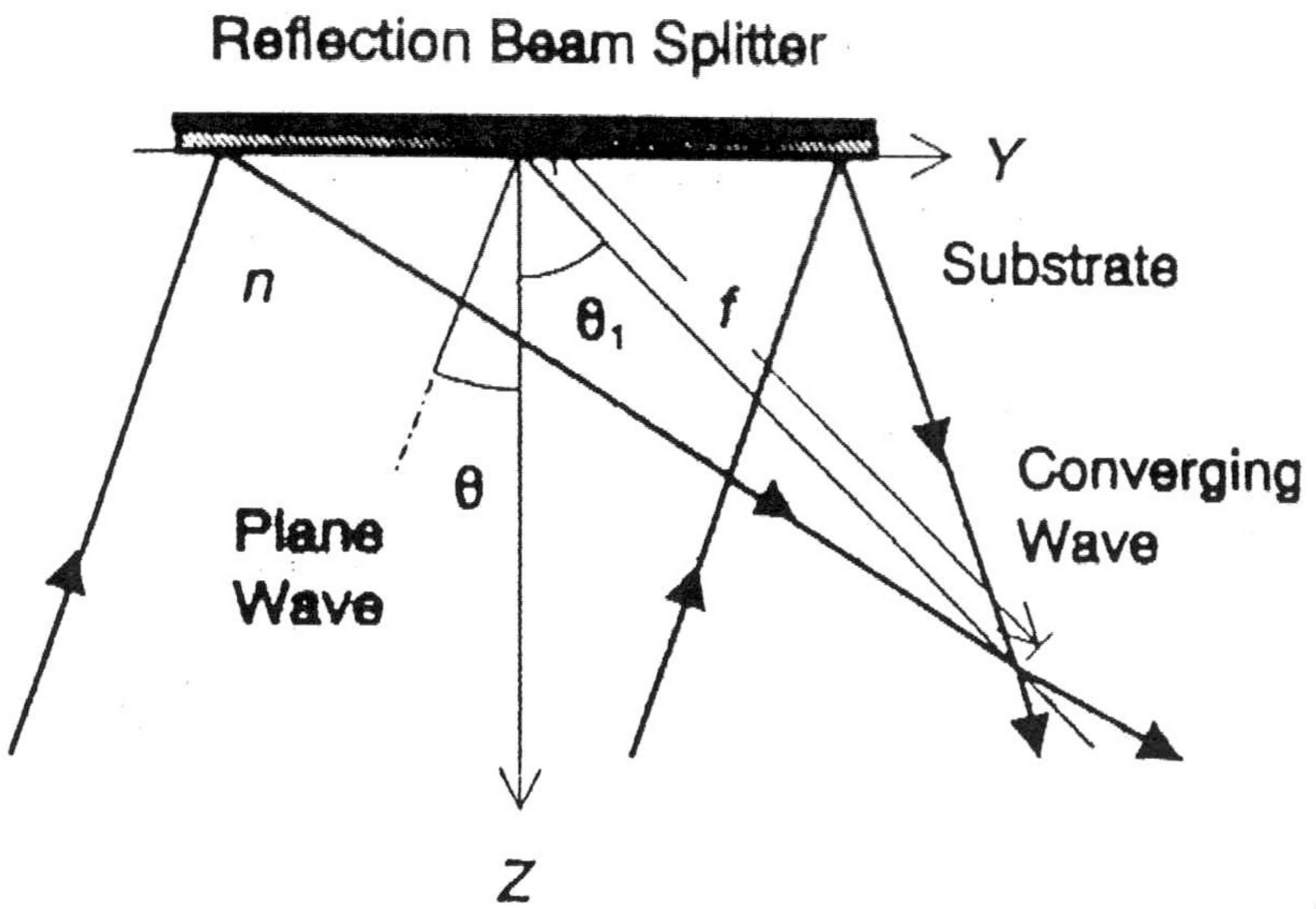




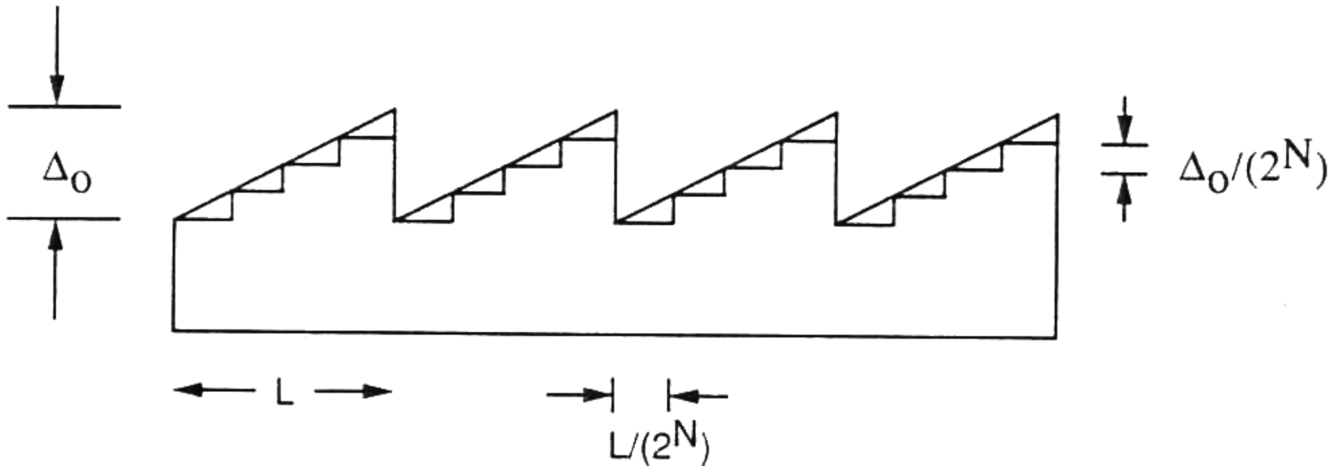
Fresnel Lens-Transmission Type



Fresnel Lens-Reflection Type



Diffractive Optical Element (DOE)



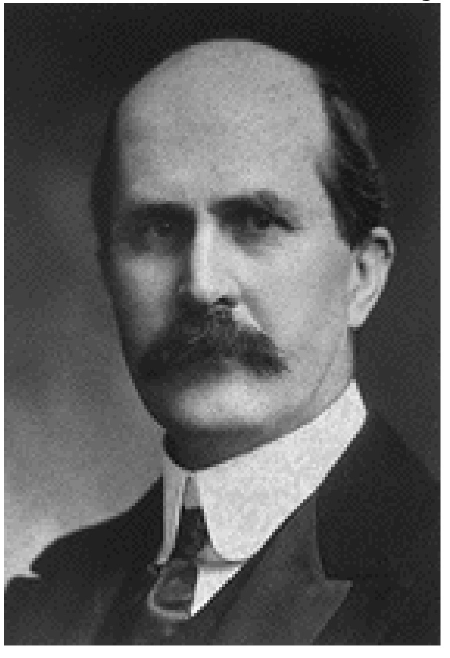
$$\eta_q = \mathrm{sinc}^2\left(\frac{q}{2^N}\right)\frac{\mathrm{sinc}^2\left(q-\frac{\phi_0}{2\pi}\right)}{\mathrm{sinc}^2\left(\frac{q-\frac{\phi_0}{2\pi}}{2^N}\right)}$$

- See lec12-11.ppt

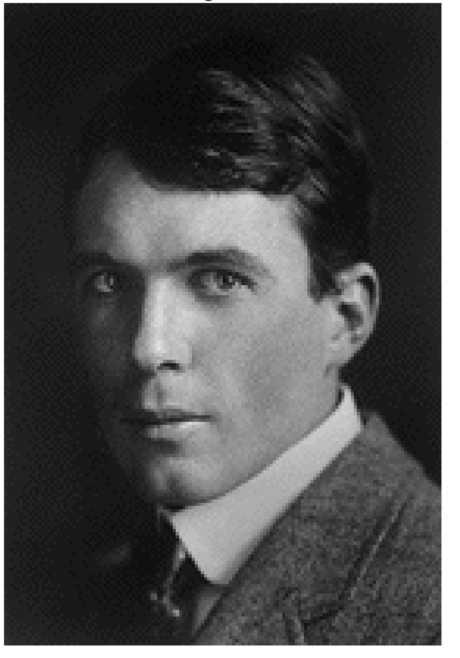
The Braggs

The Nobel Prize in Physics 1915

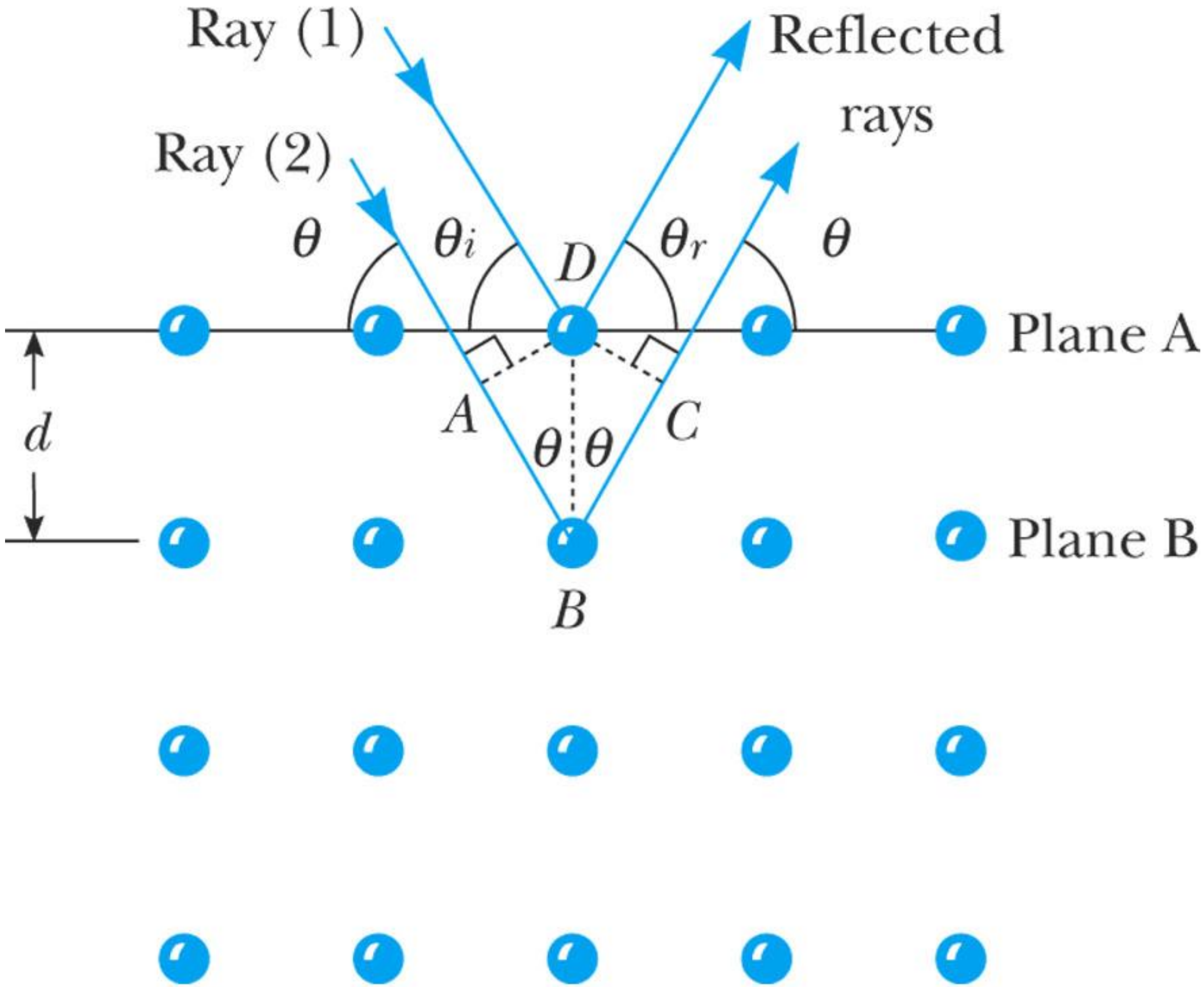
"for their services in the analysis of crystal structure by means of X-rays"



Sir William Henry Bragg
(1862-1942)

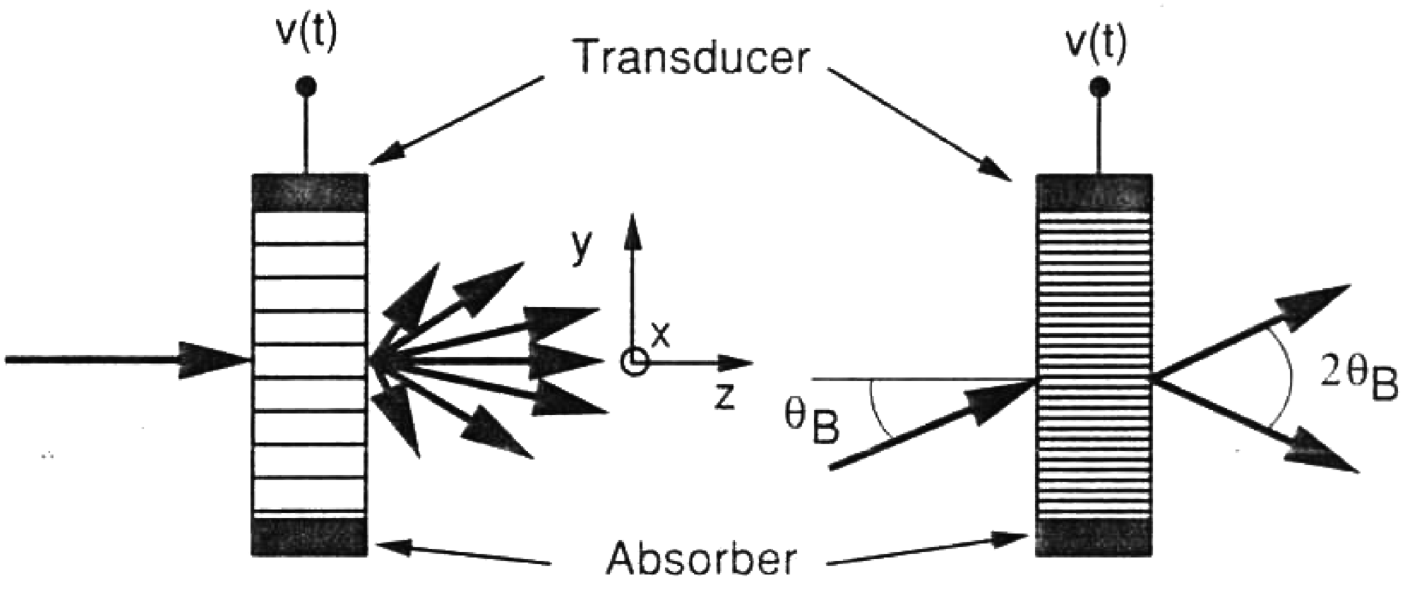


William Lawrence Bragg
(1890-1971)


Ray (1)
Ray (2)
Reflected
rays
θ
θ_i
D
θ_r
θ
Plane A
d
A
C
θ θ
Plane B
B

Acousto-Optic Modulator/Deflector (I)

- Acousto-optic effect (Photoelastic effect)



(a)

Raman-Nath regime

(b)

Bragg regime

Acousto-Optic Modulator/Deflector (II)

- Raman-Nath regime

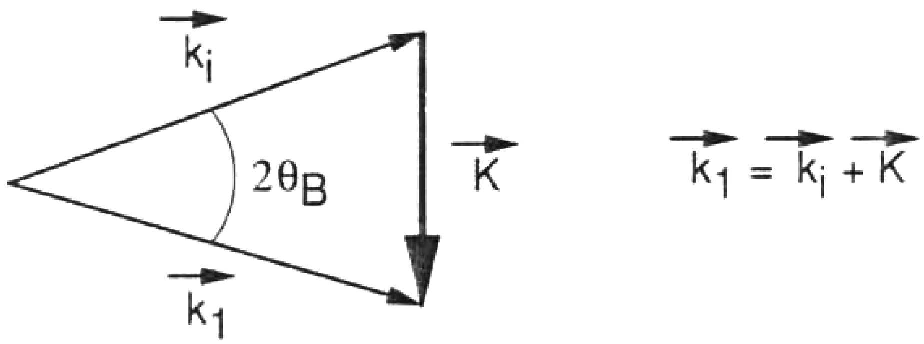
$$\sin\theta_q = q\frac{\lambda}{\Lambda} \qquad \nu_q = \nu_0\left(1+\frac{V}{c}\right)\sin\theta_q \approx \nu_0 + qf_c$$

- Bragg regime

- Energy conservation (Doppler effect)
- Momentum conservation (phase matching)

$$\sin\theta_B = \pm\frac{\lambda}{2\Lambda}$$

$$\sin\theta_B = \pm\frac{|\vec{K}|}{2|\vec{k}_i|}$$



- $$Q = \frac{2\pi\lambda_0 d}{n\Lambda^2}$$

$Q < 2\pi$ Raman - Nath

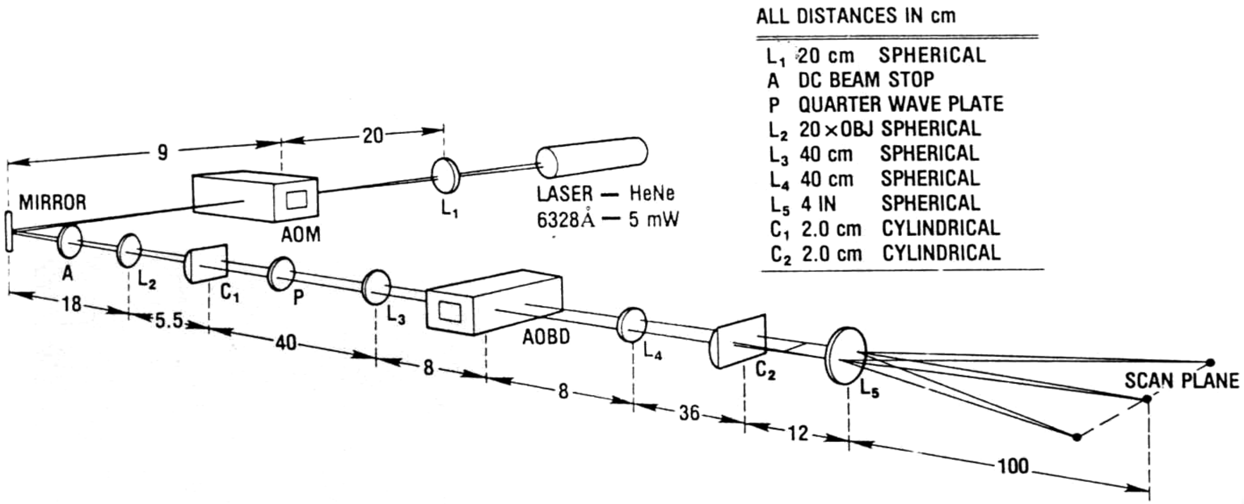
$Q > 2\pi$ Bragg

Acousto-Optic Materials

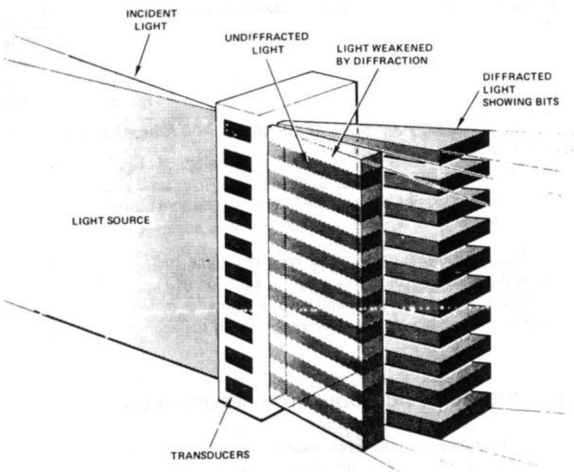
Material	Density, ρ (10^3 kg/m^3)	Velocity, v (10^3 m/s)	Index, n	Attenuation, Γ (dB/μs GHz^2)	Figures of merit: M_2 (10^{-15} s^3/kg)	Figures of merit: M_3 (10^{-15} m s^2/kg)
$LiTaO_3$	7.45	6.19	2.18	0.062	1.37	1.84
$LiNbO_3$	4.64	6.57	2.20	0.098	7.00	10.1
TiO_2	4.23	8.03	2.584	0.566	3.93	7.97
$Sr_{0.75}Ba_{0.25}Nb_2O_6$	5.40	5.50	2.299	2.20	38.6	48.8
GaP	4.13	6.32	3.31	3.80	44.6	93.5
TeO_2	6.00	4.20	2.26	6.30	34.5	32.8

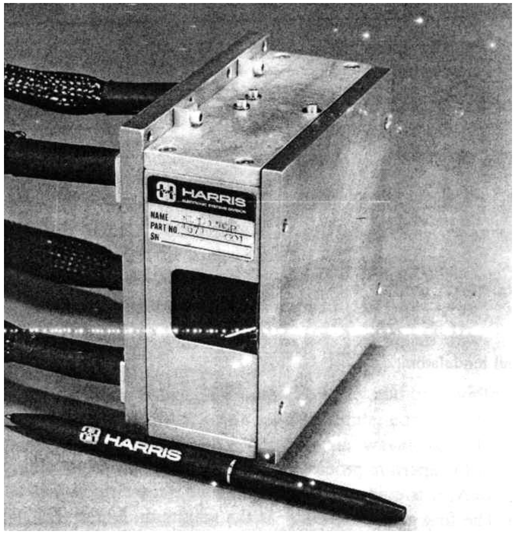
Acousto-Optic Deflector

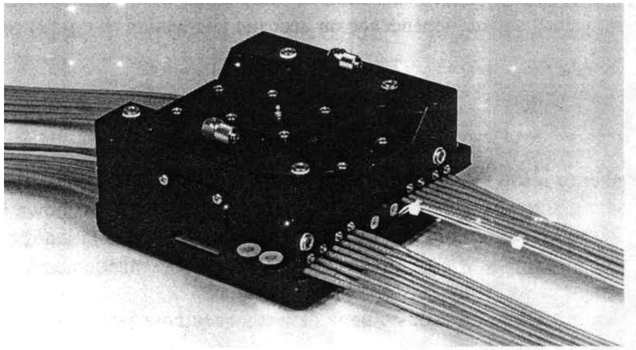
Device type	Material	Laser wavelength (μm)	Center frequency (MHz)	Bandwidth (MHz)	Aperture (μs)	Efficiency
Deflector	TeO_2 slow, shear	0.633	75	50	40	80% max.
Deflector	$LiNbO_3$	0.633	1600	1050	1.0	1.2%/W
Deflector	$LiNbO_3$	0.633	2500	1600	2.4	1.8%/W



Acousto-Optic Modulator (I)







Typical Multichannel Modulator Specifications

Number of contiguous channels	64	32
Channel separation	0.25 mm	0.5 mm
Rise time	2 nsec	2 nsec
Diffraction efficiency	30% at 633 nm	50% at 633 nm
Cross talk isolation	30 dB	30 dB

Acousto-Optic Modulator (II)

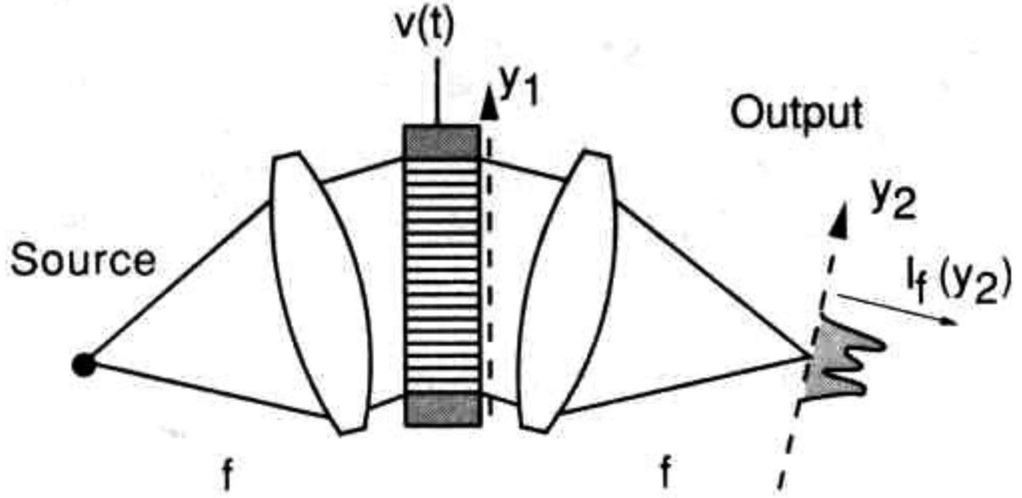
$$\upsilon(t) = A(t)\sin\left[2\pi f_c t - \psi(t)\right]$$

$$\Delta n(y;t) = \sigma\upsilon\left(\frac{y}{V} + t - \tau_0\right)$$

$$U(y;t) = U_0 \exp\left\{ j\frac{2\pi\sigma d}{\lambda_0} A\left(\frac{y}{V} + t - \tau_0\right)\sin\left[2\pi f_c\left(\frac{y}{V} + t - \tau_0\right) - \psi\left(\frac{y}{V} + t - \tau_0\right)\right]\right\}\mathrm{rect}\,\frac{y}{L}$$

$$U_{\pm 1} \approx \pm\frac{\pi\sigma d}{\lambda_0} U_0 A\left(\frac{y}{V} + t - \tau_0\right) e^{\mp j\psi(y/V + t - \tau_0)} e^{\pm j2\pi y/\Lambda} e^{\pm j2\pi f_c(t-\tau_0)}\mathrm{rect}\,\frac{y}{L}$$

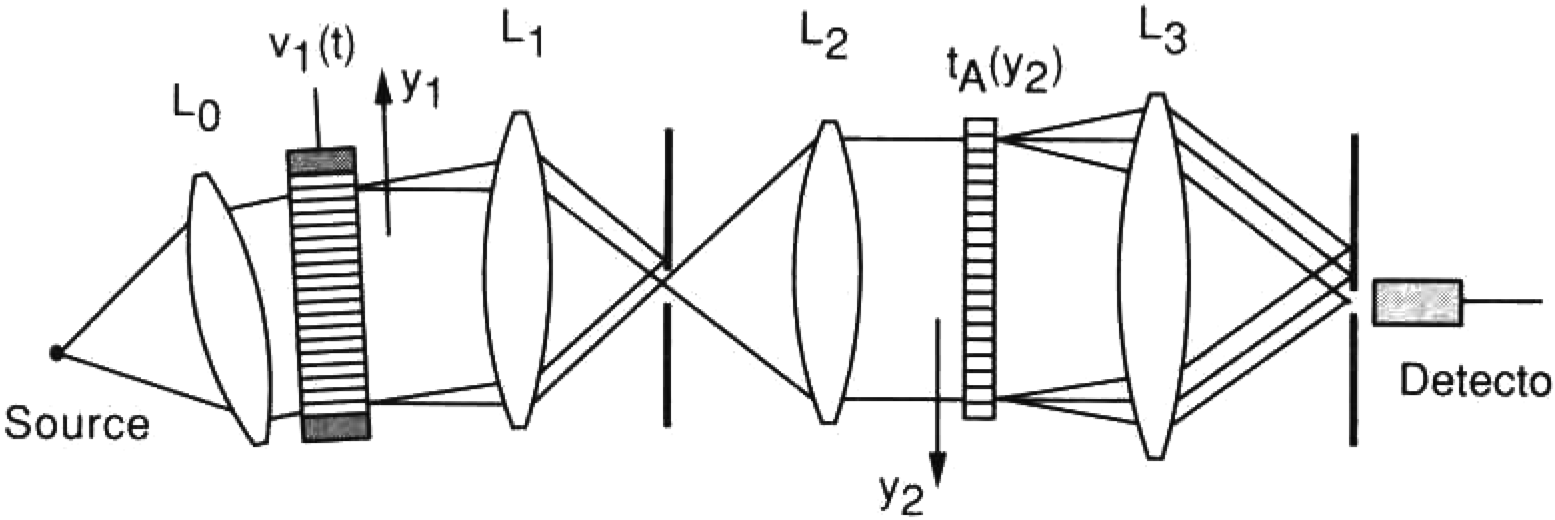
Bragg Cell Spectrum Analyzer



$$U_f(y_2;t) = C'\int_{-\infty}^{\infty} s\left(\frac{y_1 + Vt - V\tau_0}{V}\right) \mathrm{rect}\,\frac{y_1}{L}\exp\left(-j\frac{2\pi y_1 y_2}{\lambda f}\right) dy_1$$

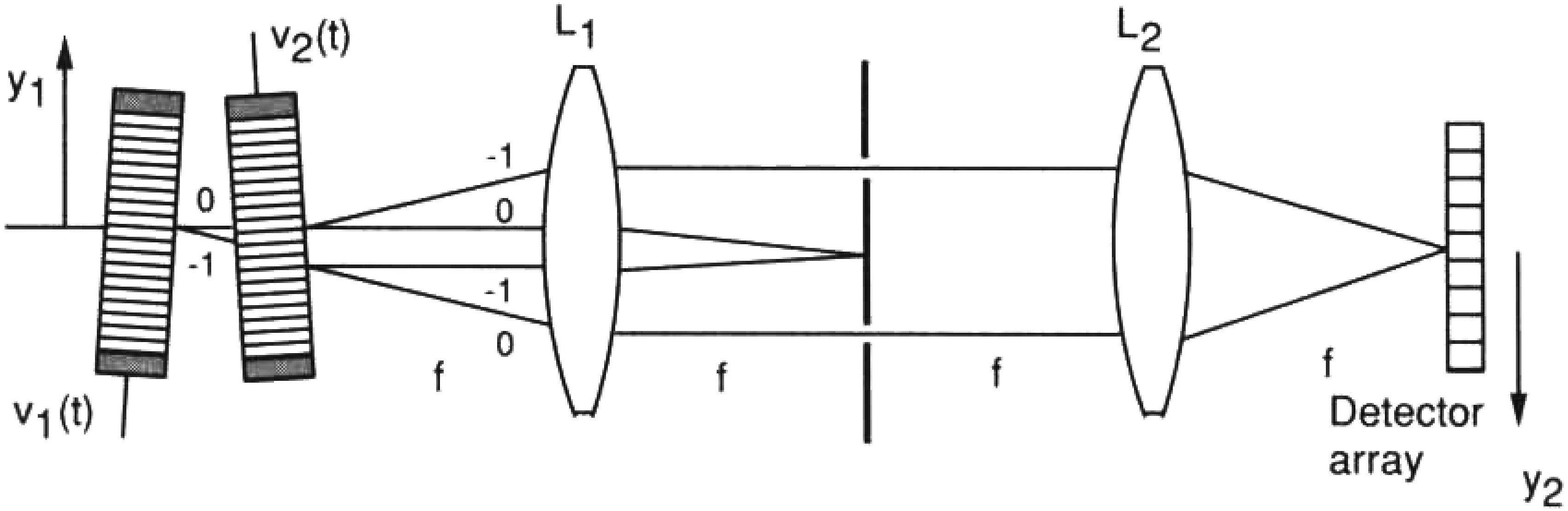
$$I_f(y_2) = \left| S\left(\frac{Vy_2}{\lambda f}\right)\exp\left[j\frac{2\pi}{\lambda f}Vy_2(t-\tau_0)\right]\right|^2 = \left|S\left(\frac{Vy_2}{\lambda f}\right)\right|^2$$

Space-Integrating Correlator



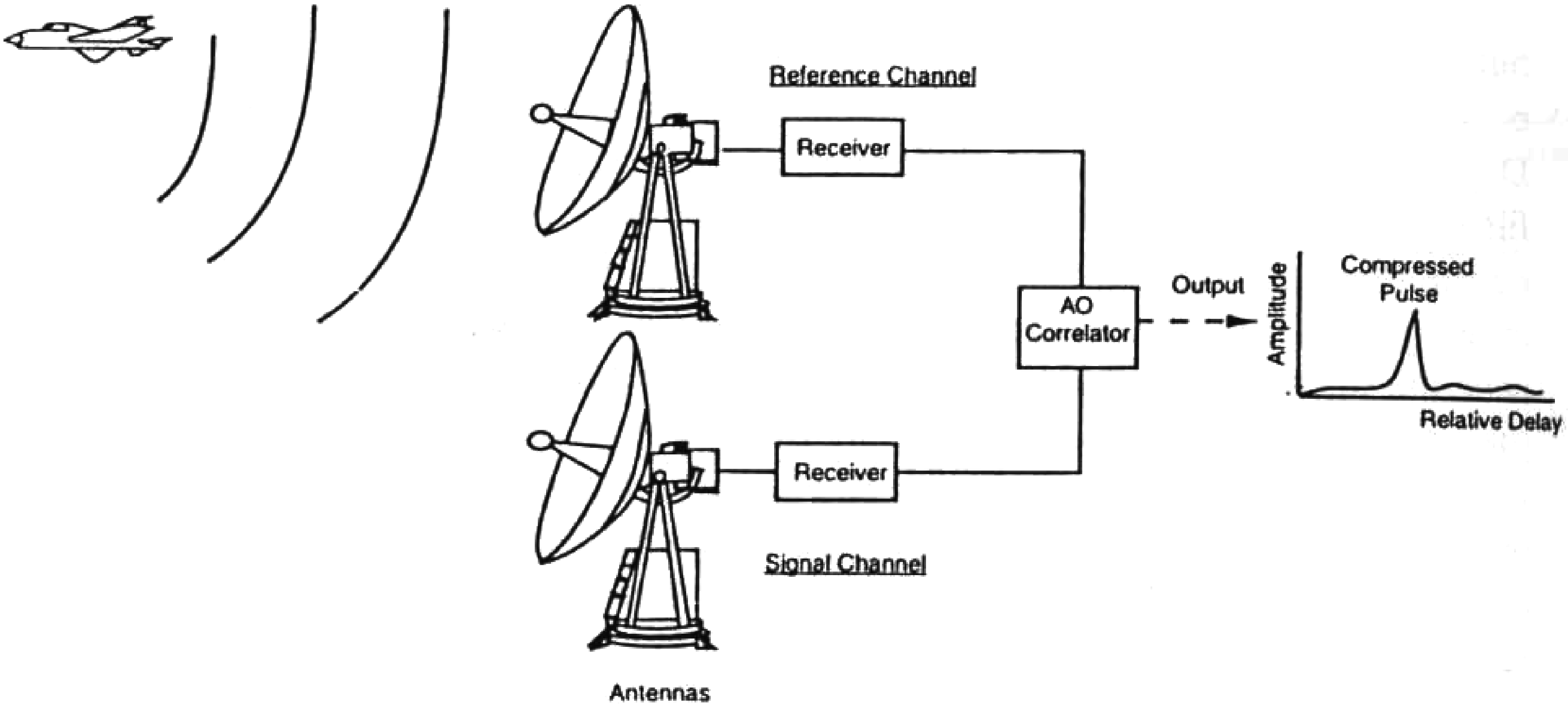
$$i_d(t) = \left| \int_{-\infty}^{\infty} s_1\left(\frac{y_2 + Vt - V\tau_0}{V}\right) s_2^*(y_2)\,\mathrm{rect}\,\frac{y_2}{L}\,dy_2 \right|^2$$

Time-Integrating Correlator



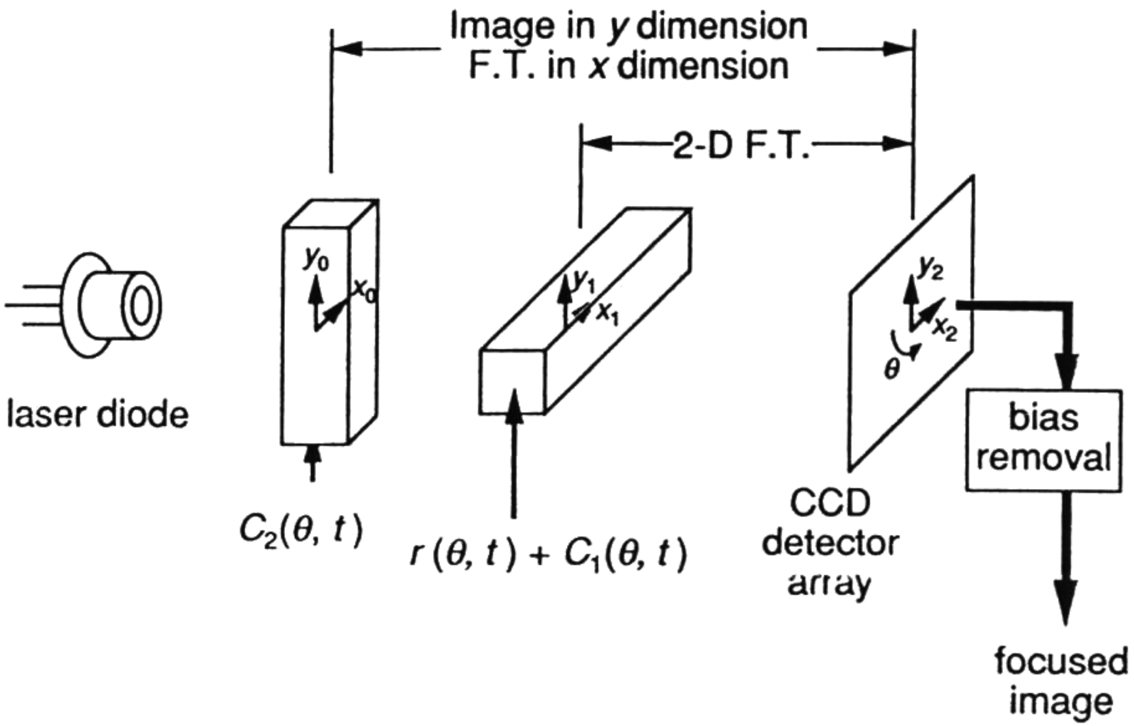
$$c(\tau) = \int_{\Delta T'} s_1(t') s_2^*(t'+\tau) dt' = |c(\tau)| e^{j\phi(\tau)}$$

Intercept Receiver using AO Correlator



RAPID SAR

- Real-time Acousto-optic Programmable Imaging and Display for SAR using AOD



Photonic Switch using AO