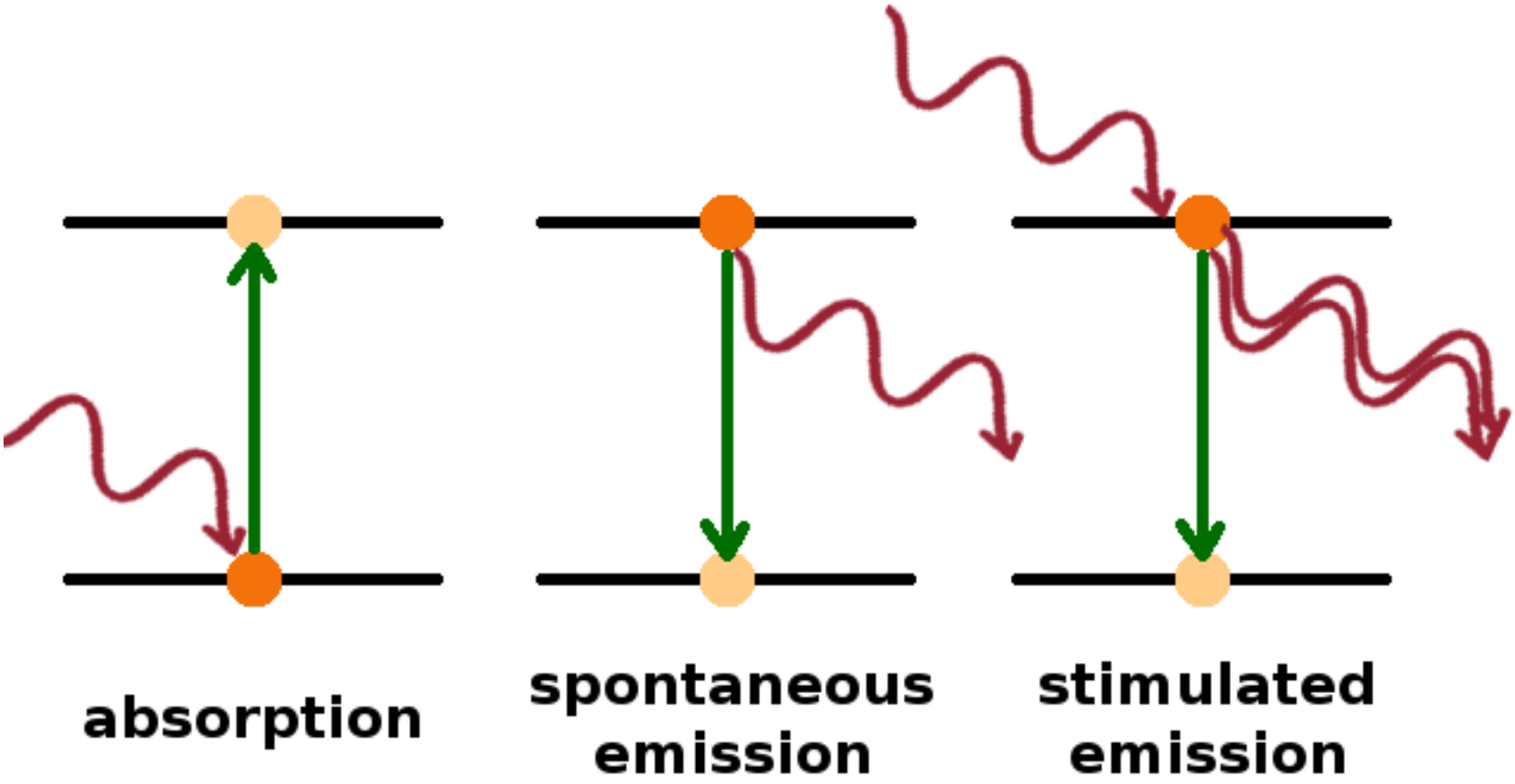
Differences – LED and LASER

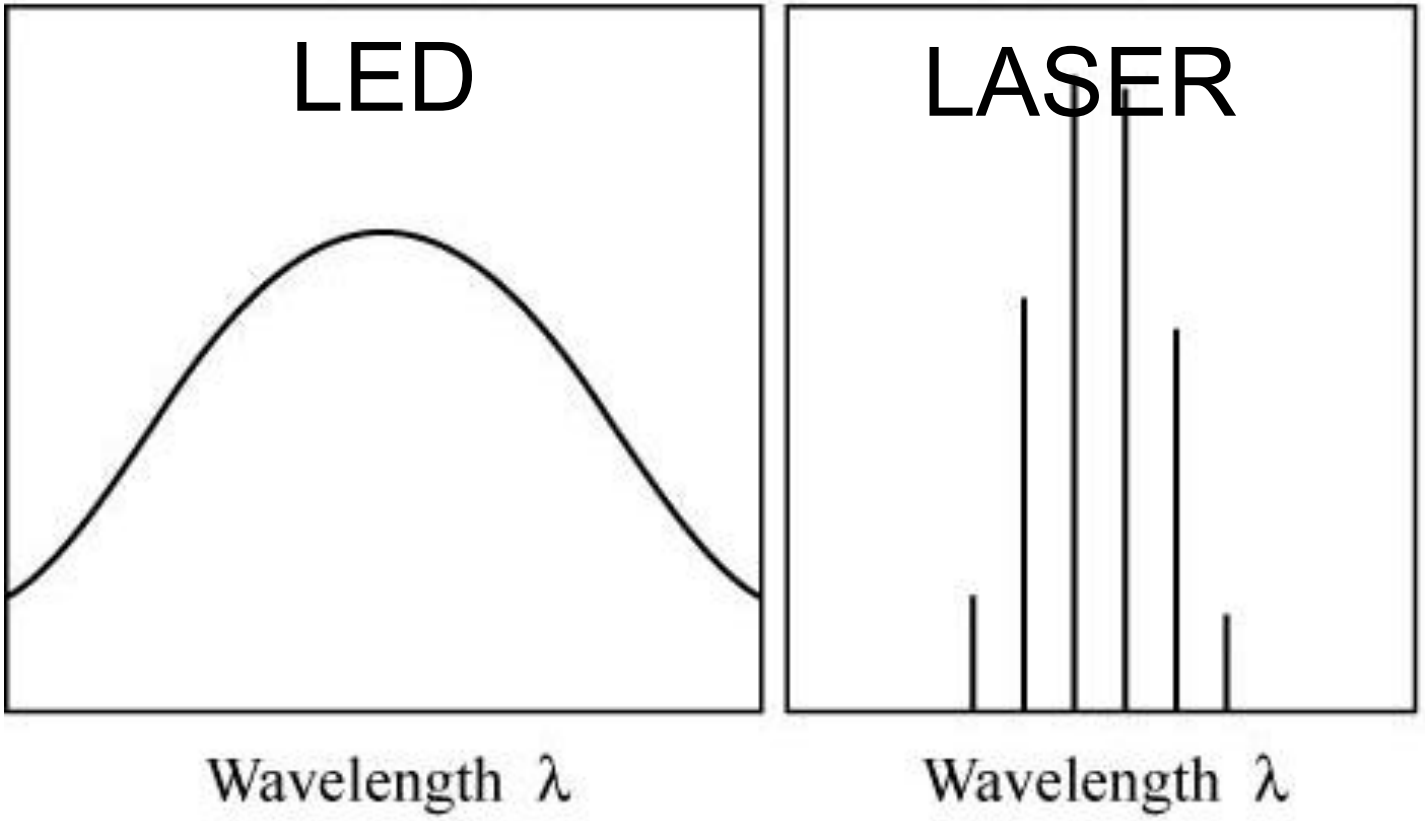
- Spontaneous vs. stimulated emission
- Smaller linewidth – LED/LASER : (>5nm)/(<1 nm), spectral purity
- Directivity – LASER light is directive
- Coherence – Phase coherence for LASER
- Light intensity – LASER has higher power
- Efficiency – LASER higher efficiency
- LED to LASER Transition – Threshold current or threshold power
- Modulation bandwidth – Higher speed for laser

Spontaneous vs. Stimulated Emission



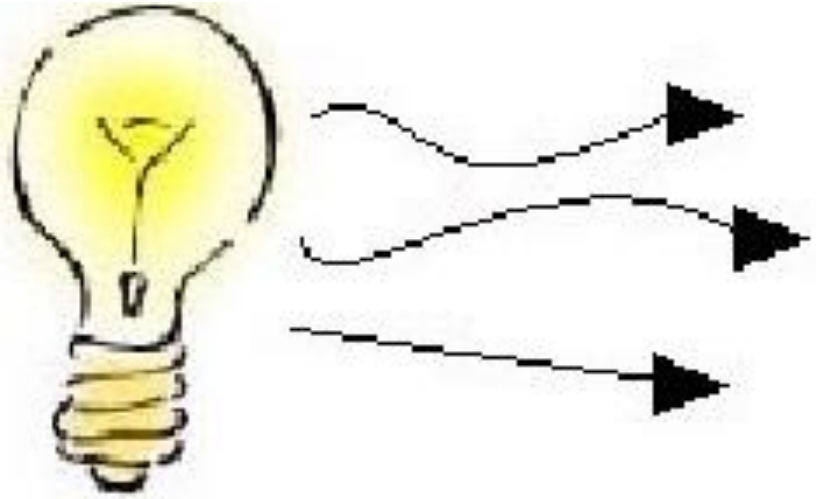
- Radiative recombination in the presence of another photon
- Same wavelength and phase
- Carrier lifetime – ns versus ps

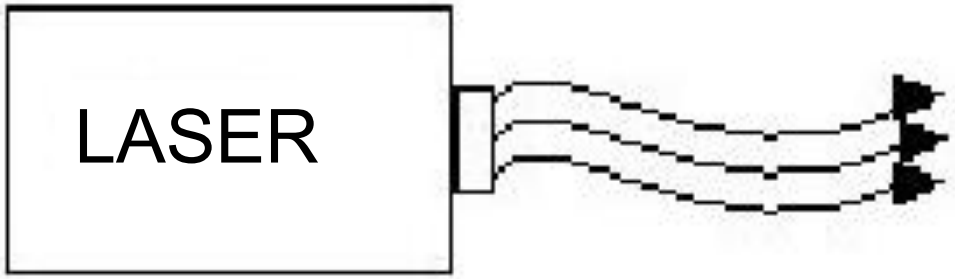
Linewidth

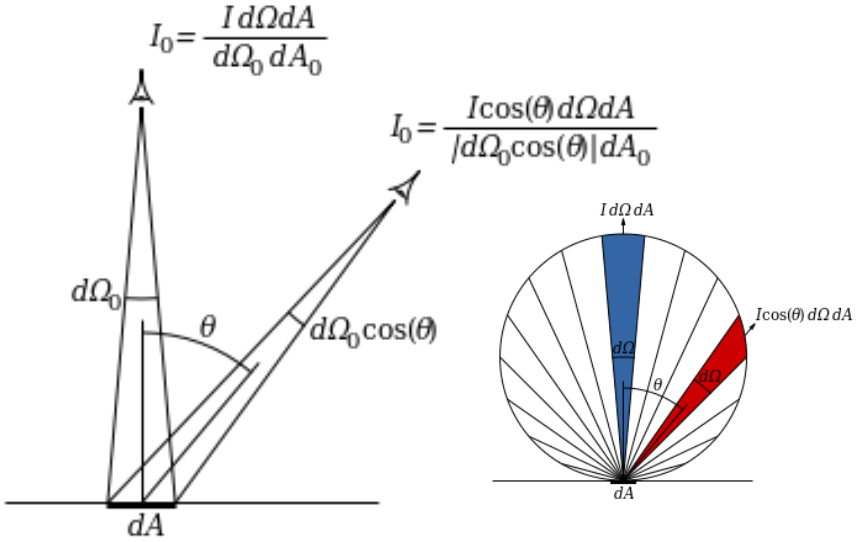


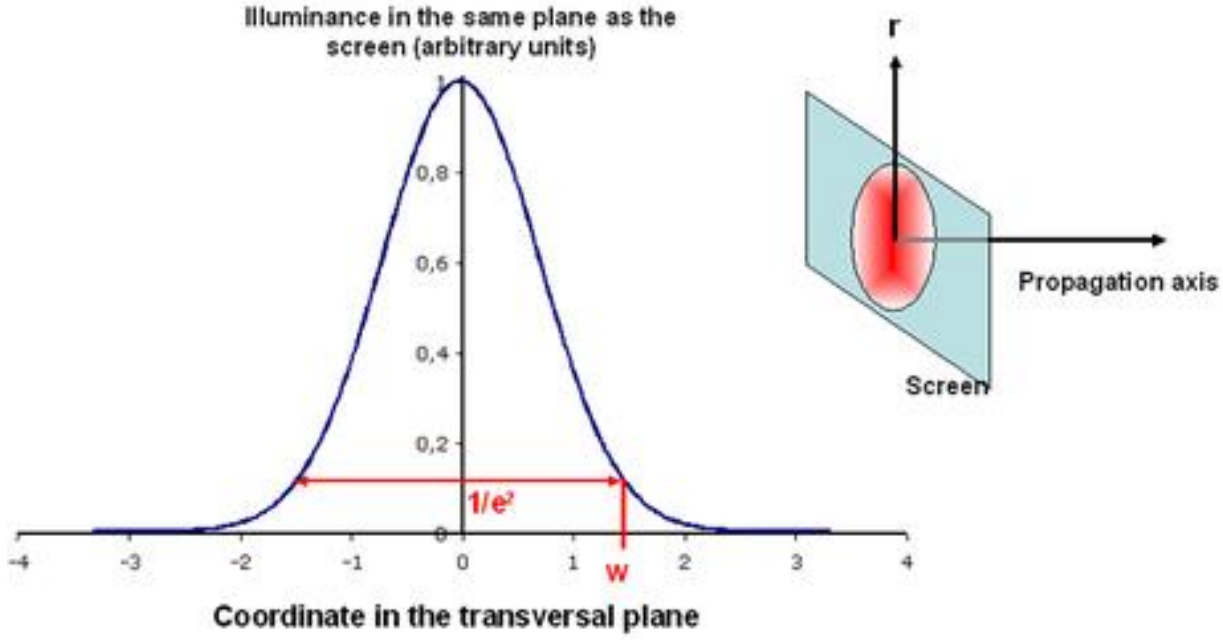
- FWHM – LED10-50 nm; LASER < 1 nm
- LED – Emission governed by Fermi-Dirac Distribution
- LASER – Stimulated emission governed by Fermi's golden rule

Directivity



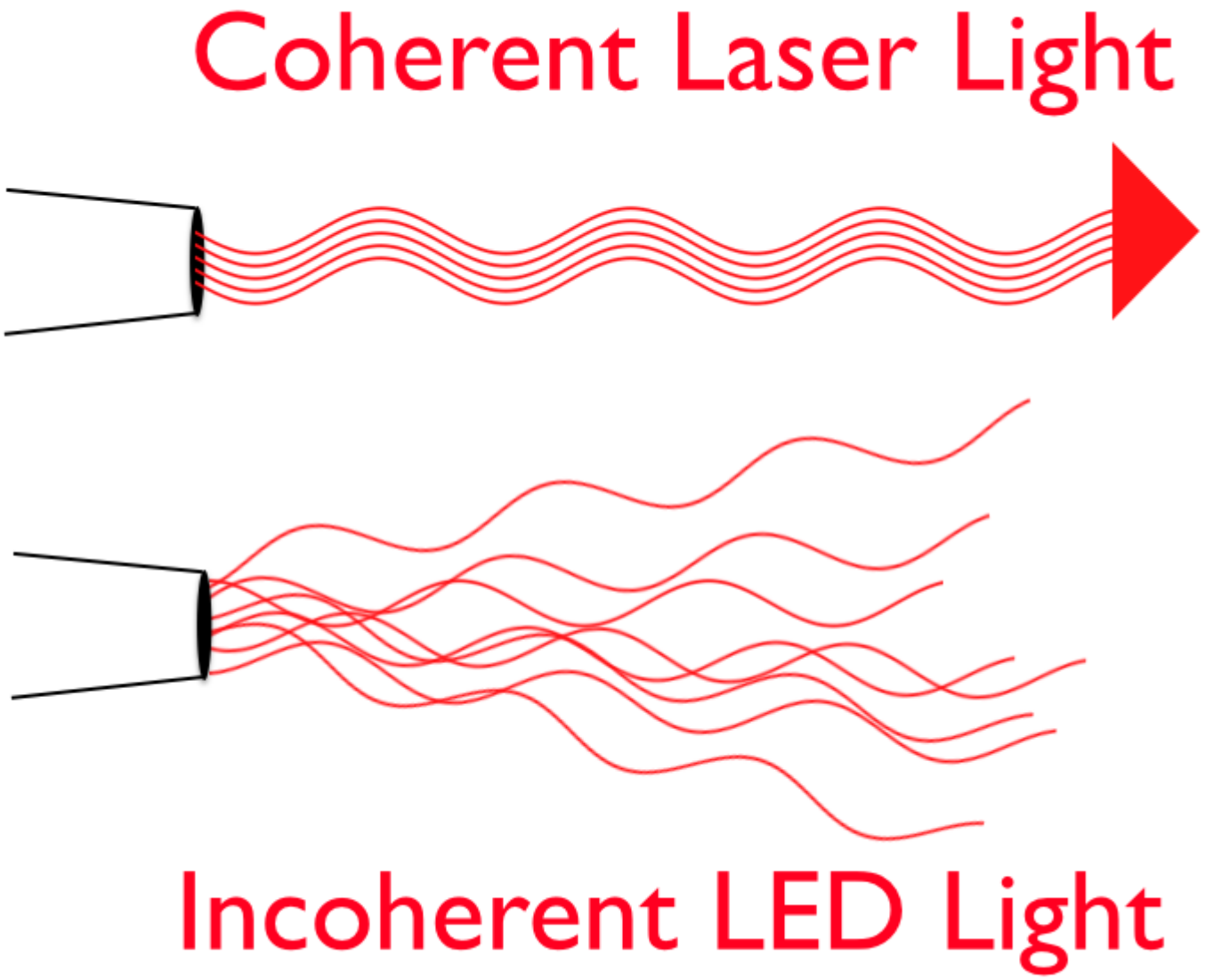




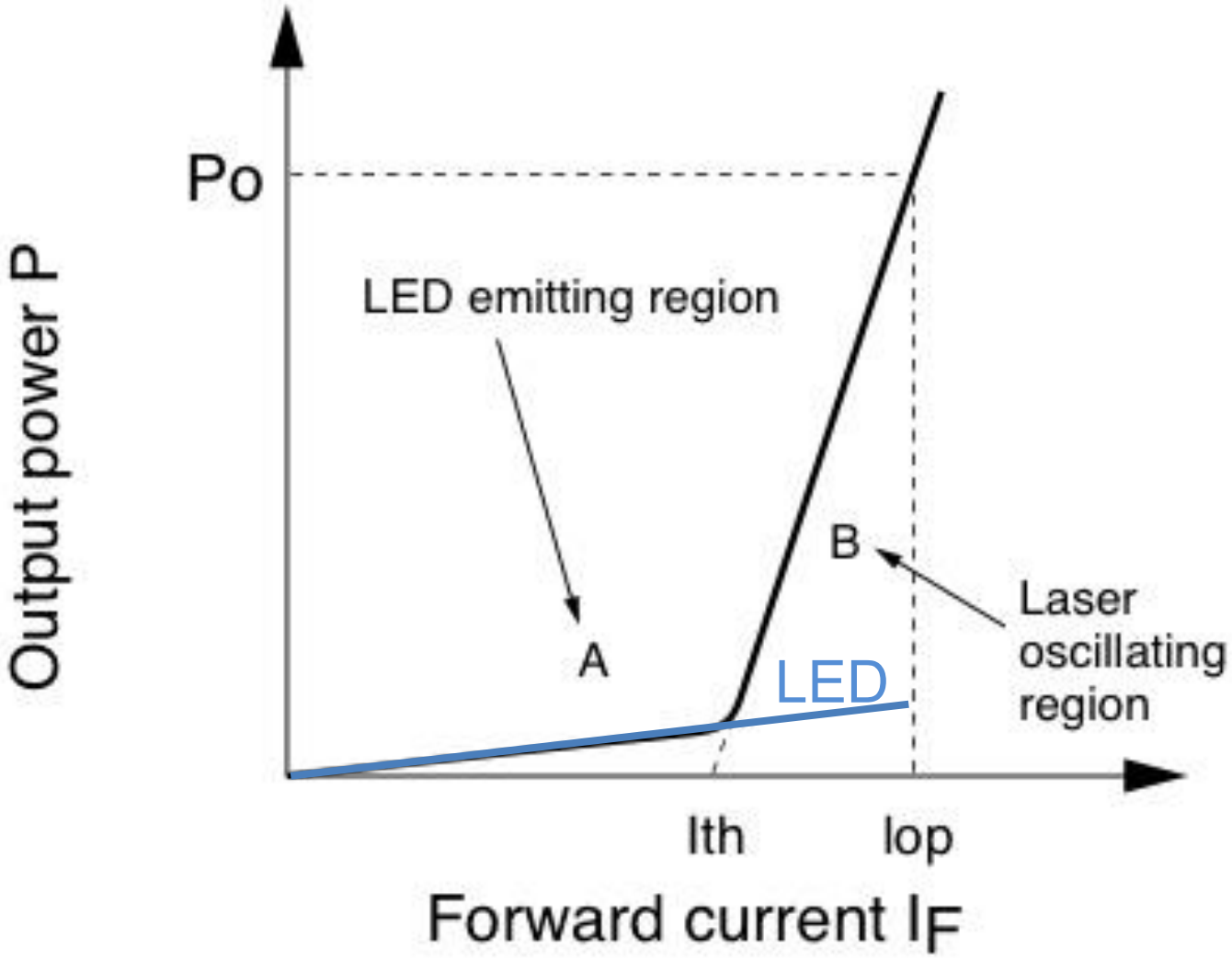


- LED – Generally follows Lambert's cosine law
- LASER – Gaussian

Coherence

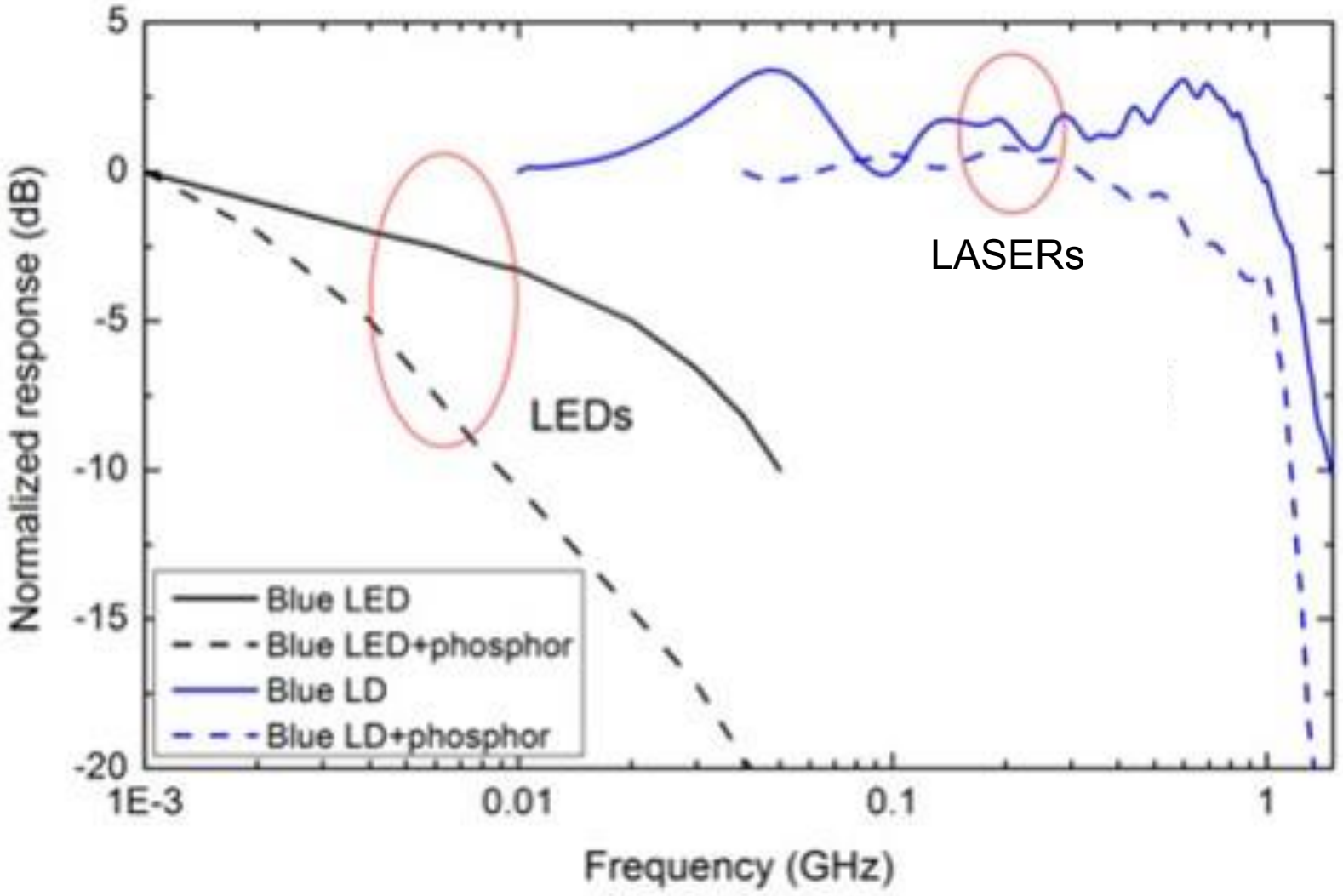


Light Intensity and Efficiency



Output power vs. Forward current (P-I_F)

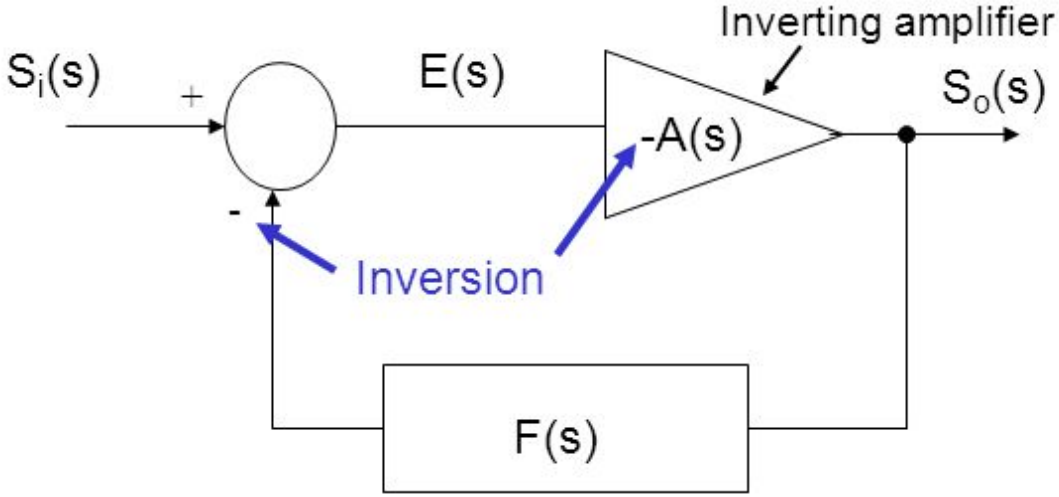
Modulation Bandwidth



- Higher modulation bandwidth for laser

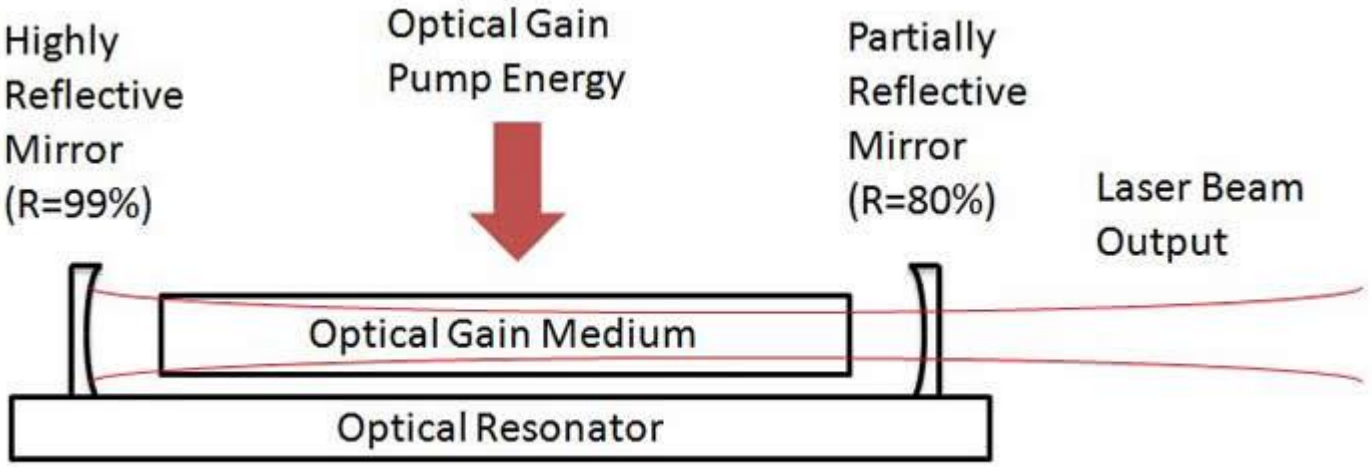
LASER from LED

Electronic Oscillator = Large Gain Amplifier + Frequency Selective Network



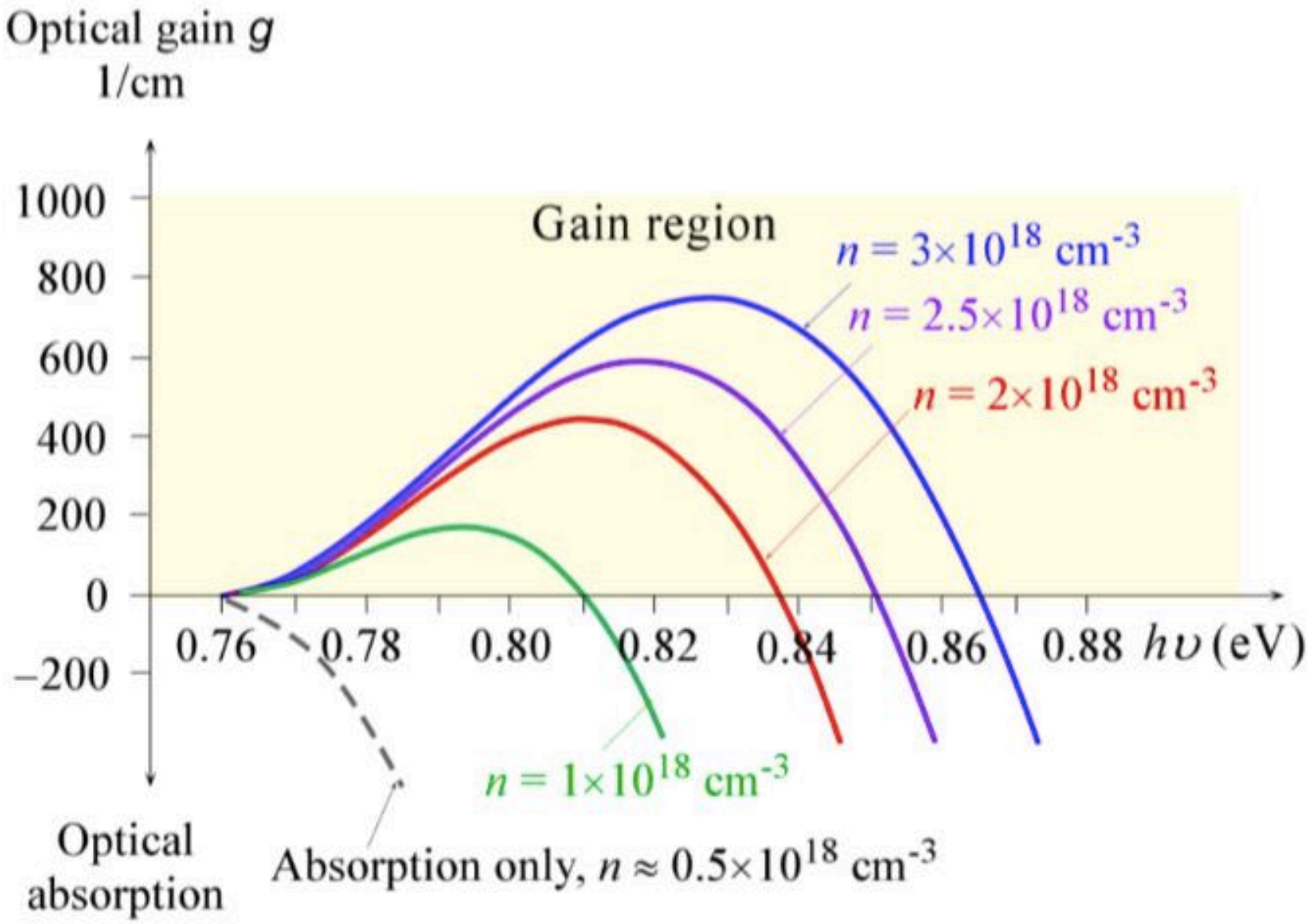
$$\frac{S_O}{S_i}(s) = \frac{A(s)}{1 - A(s)F(s)}$$

LASER = Large Gain LED + Optical Cavity

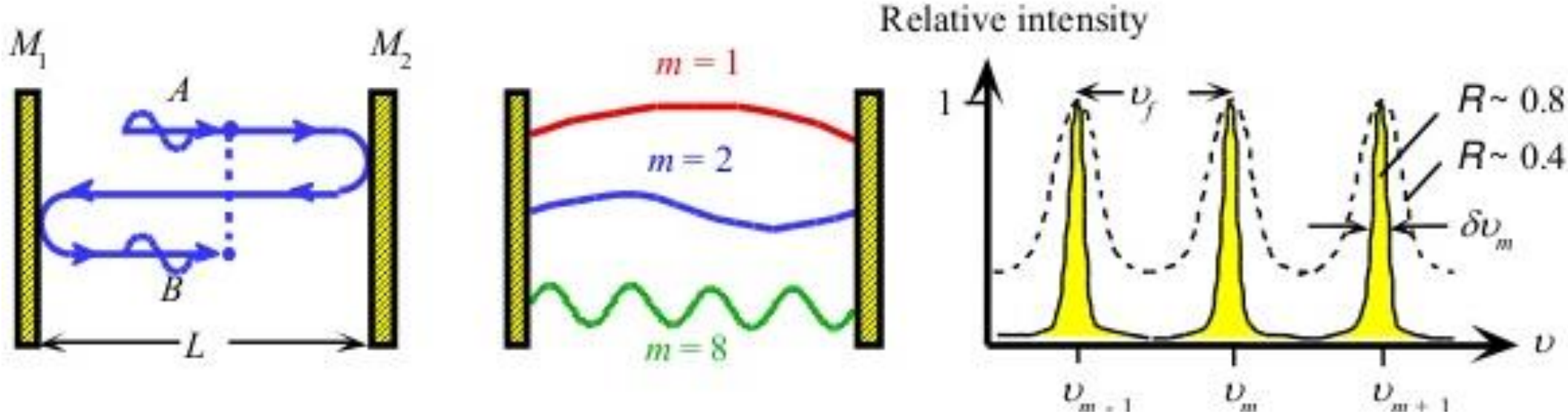


Laser Building Blocks: the Optical Gain Medium and the Optical Resonator

Optical Gain



Optical Resonators



- Standing EM modes of certain λ
- Higher reflectivity better quality factor

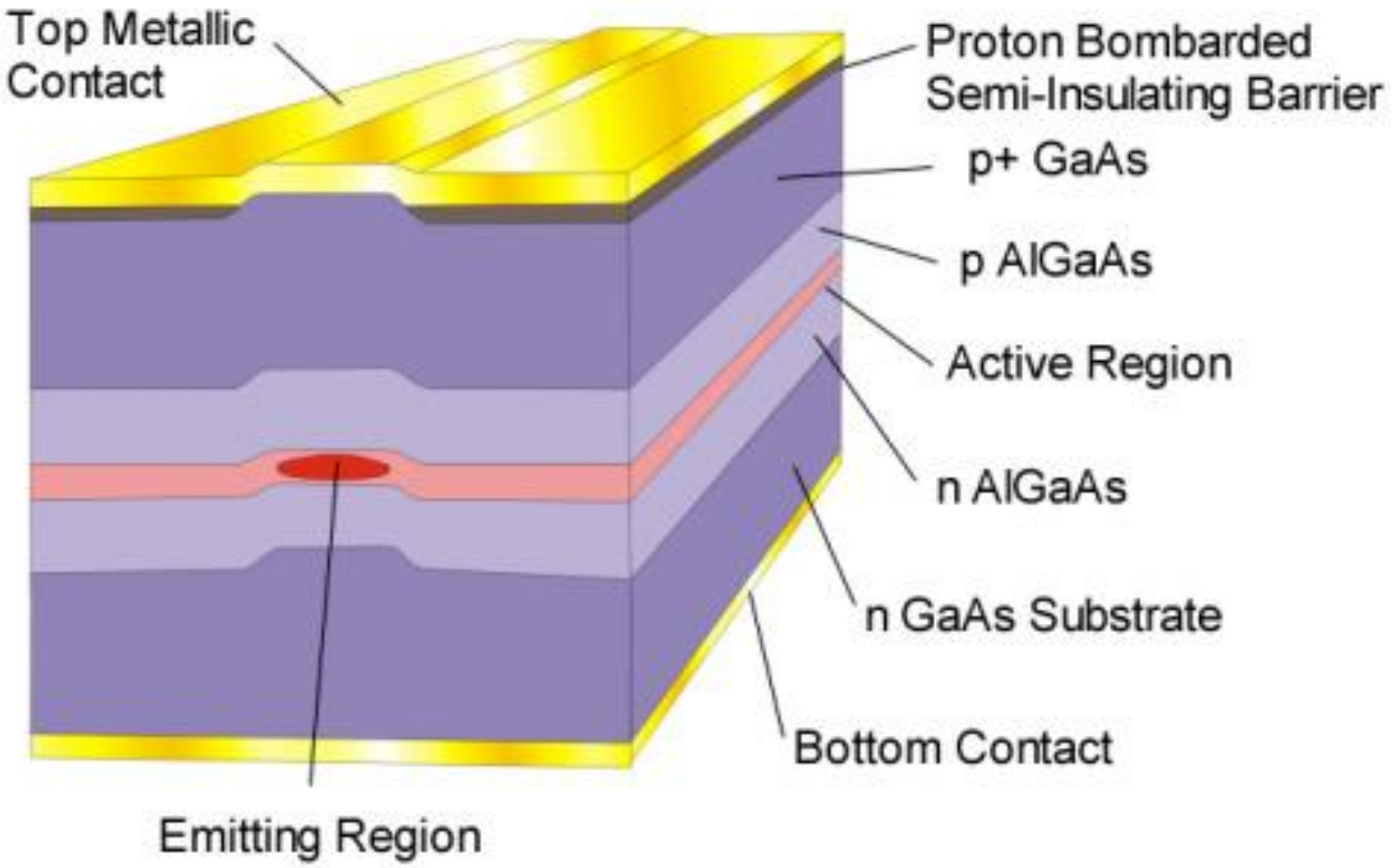
Transient Response – Relaxation Oscillations

$$\frac{dN(t)}{dt} = \frac{I(t)}{q \cdot V_a} - g_0 \cdot \frac{[N(t) - N_0] \cdot S(t)}{1 + \varepsilon \cdot S(t)} - \frac{N(t)}{\tau_n} \quad (1)$$

$$\frac{dS(t)}{dt} = \Gamma \cdot g_0 \cdot \frac{[N(t) - N_0] \cdot S(t)}{1 + \varepsilon \cdot S(t)} - \frac{S(t)}{\tau_p} + \frac{\Gamma \cdot \beta}{\tau_n} \cdot N(t) \quad (2)$$

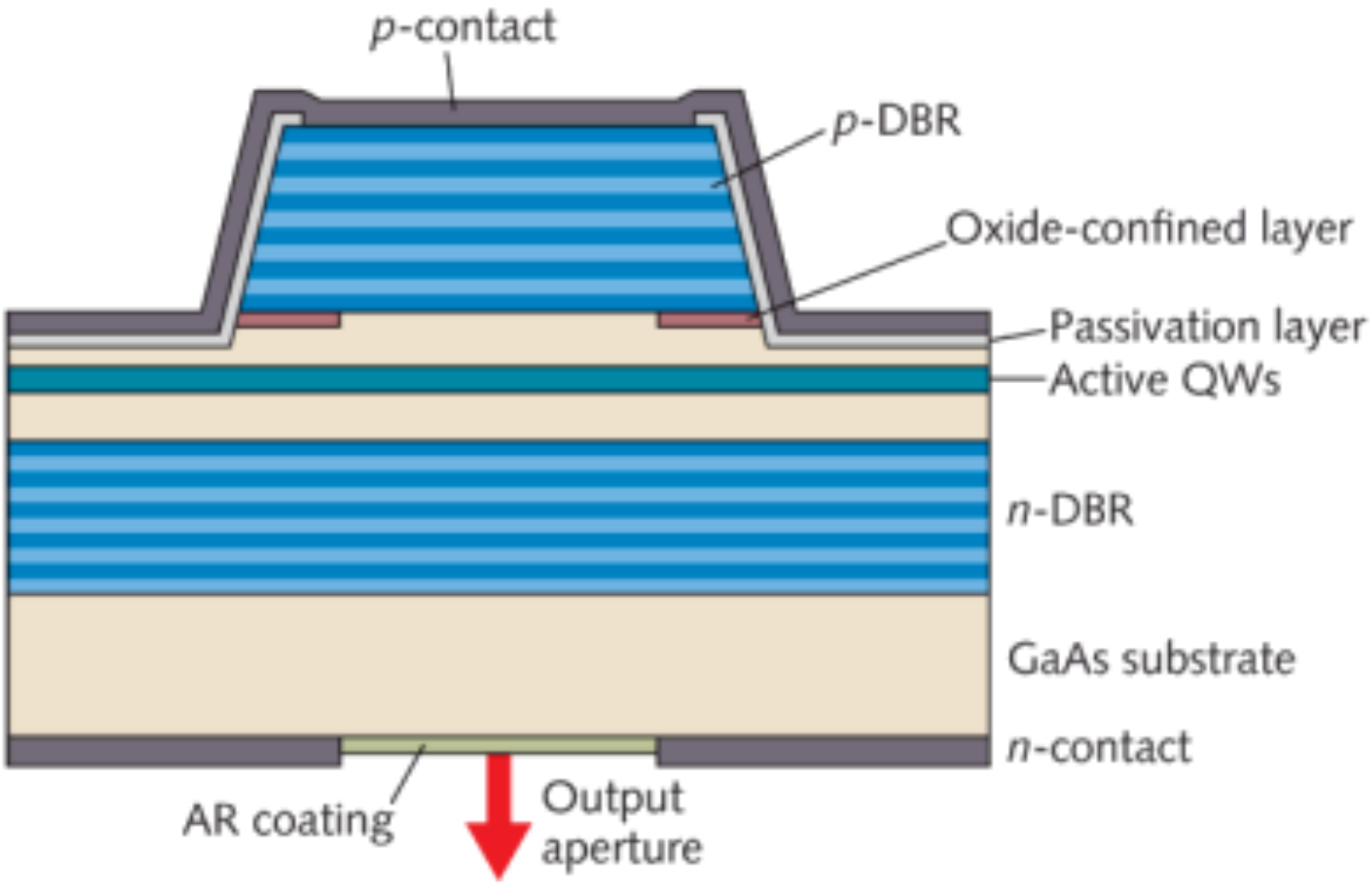
TransientResponseOfASemiconductorLaser.cdf

Fabry-Perot Laser – Edge Emitting



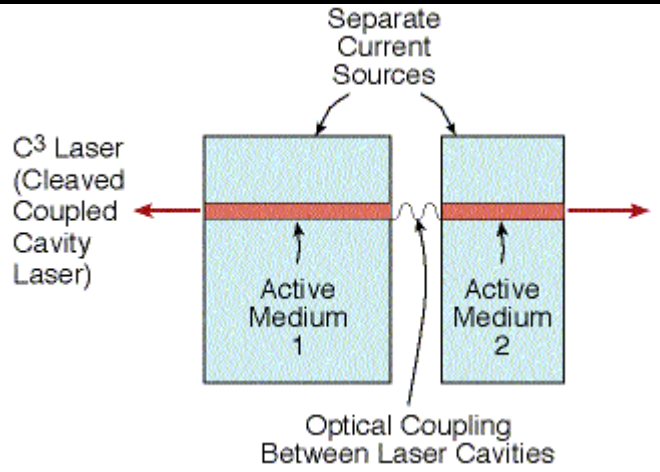
VCSEL – Surface Emitting Laser

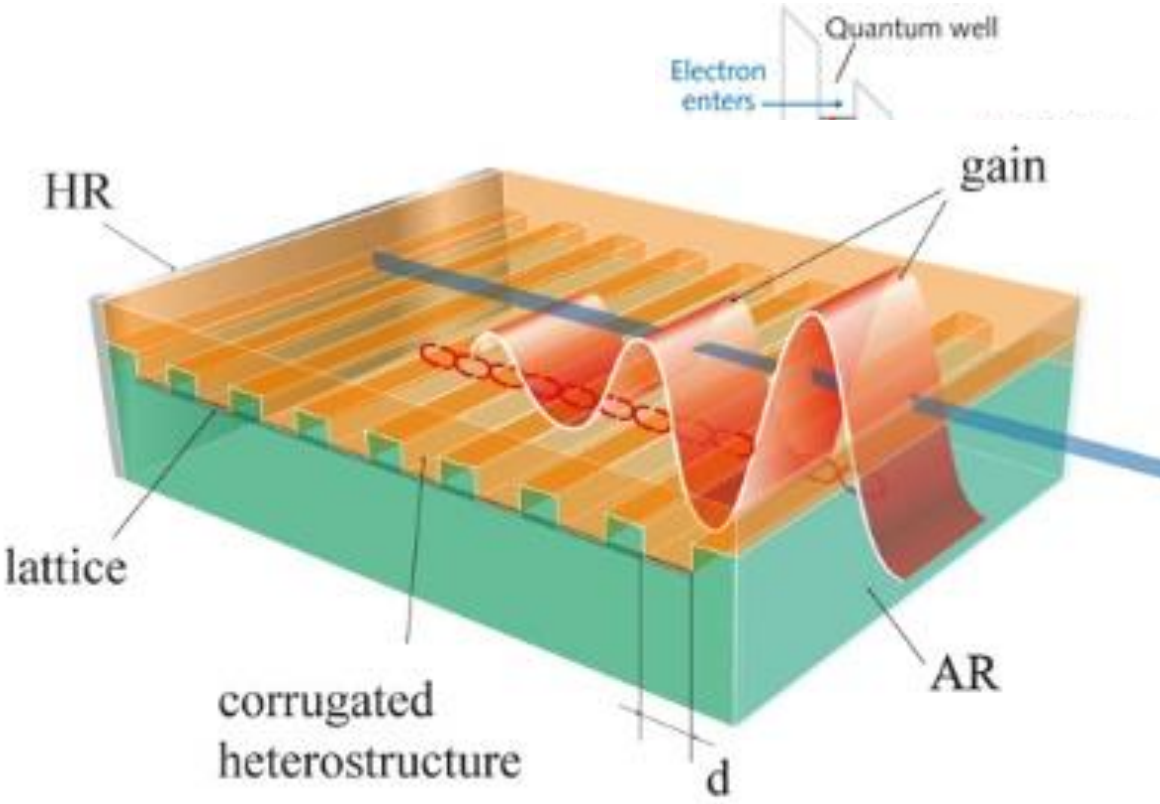
this is useful

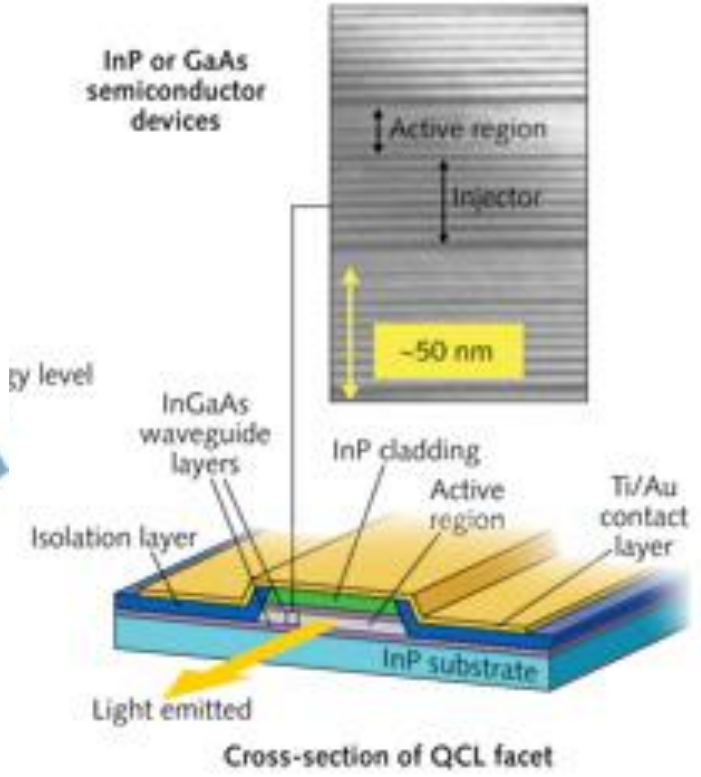


Various Types of Semiconductor Lasers

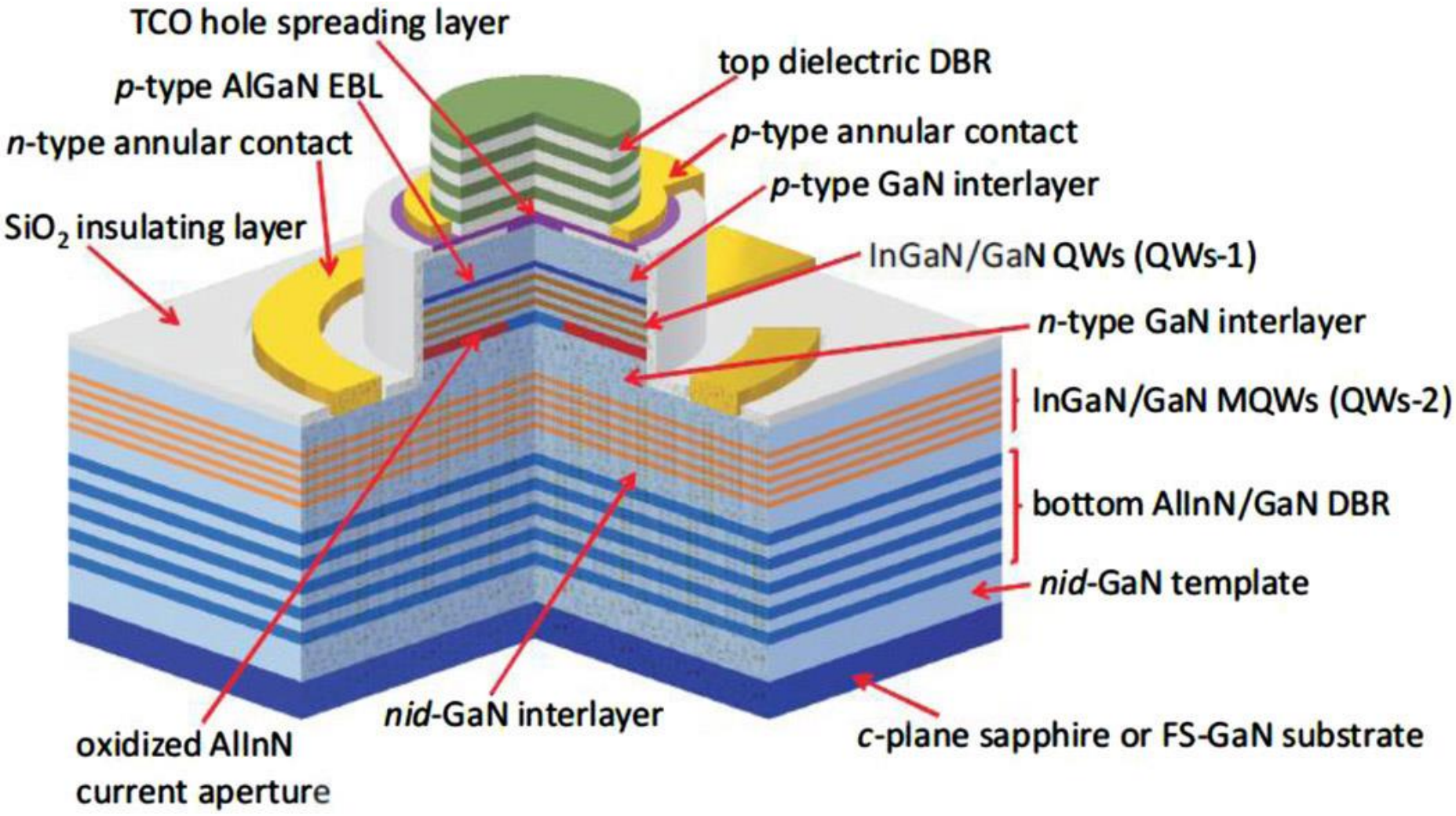
- Cleaved coupled laser
- Quantum cascade laser
- DFB Laser



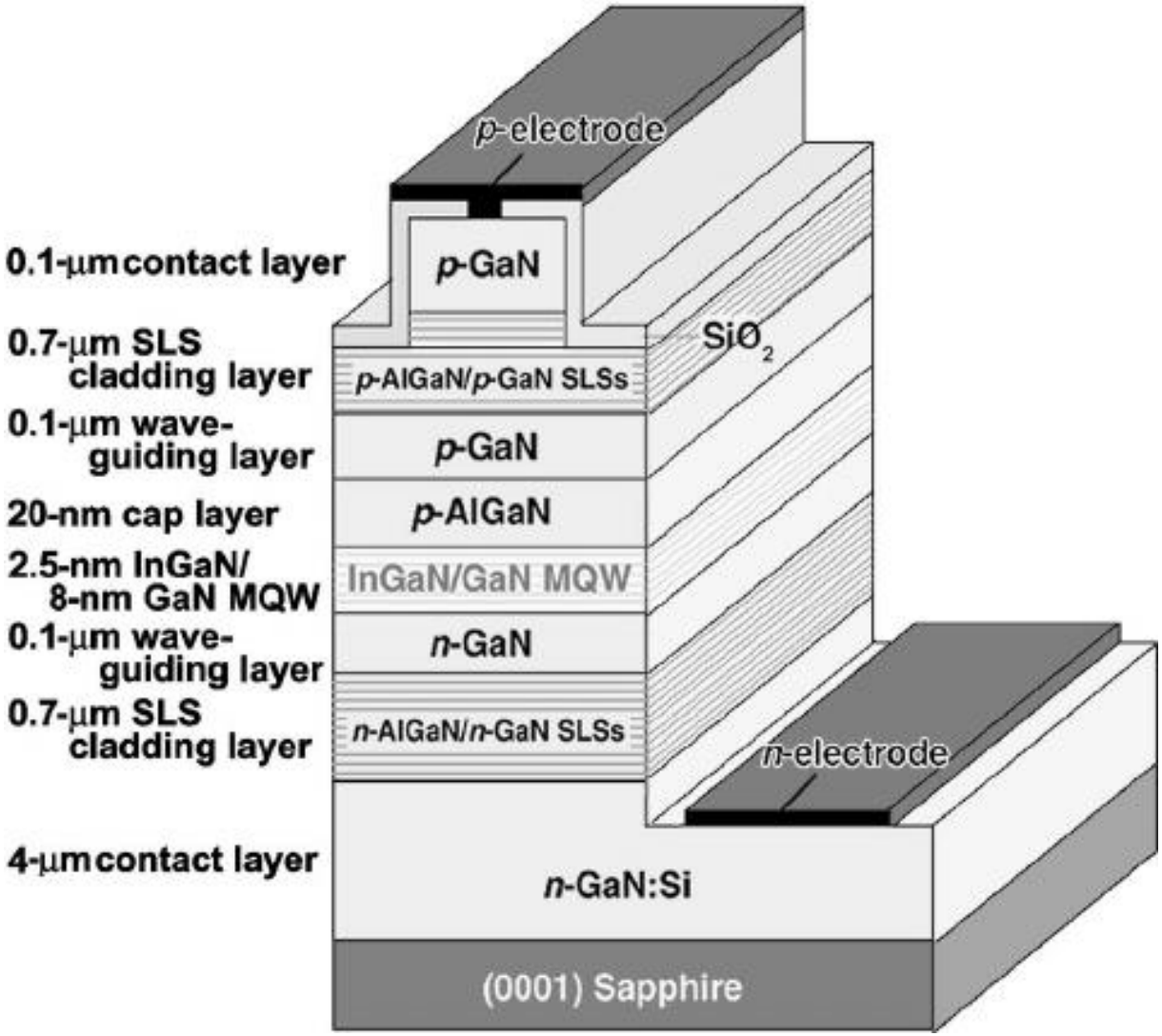




GaN Lasers


TCO hole spreading layer
top dielectric DBR
p-type AlGaN EBL
p-type annular contact
n-type annular contact
p-type GaN interlayer
SiO2 insulating layer
InGaN/GaN QWs (QWs-1)
n-type GaN interlayer
InGaN/GaN MQWs (QWs-2)
bottom AlInN/GaN DBR
nid-GaN template
nid-GaN interlayer
oxidized AlInN
current aperture
c-plane sapphire or FS-GaN substrate

GaN Lasers


p-electrode
0.1-μm contact layer
p-GaN
SiO2
0.7-μm SLS cladding layer
p-AlGaN/p-GaN SLSs
0.1-μm wave-guiding layer
p-GaN
20-nm cap layer
p-AlGaN
2.5-nm InGaN/ 8-nm GaN MQW
InGaN/GaN MQW
0.1-μm wave-guiding layer
n-GaN
0.7-μm SLS cladding layer
n-AlGaN/n-GaN SLSs
n-electrode
4-μm contact layer
n-GaN:Si
(0001) Sapphire

Useful Research Problems

- Choice of gain medium
- Choice of optical resonator
- Gain medium active region – Quantum well, wire or dots
- Increasing carrier capture
- Reduced chirp – wavelength fluctuation
- Temperature independency
- Single mode
- Effective carrier distribution
- Highly reflective mirror

Thank You