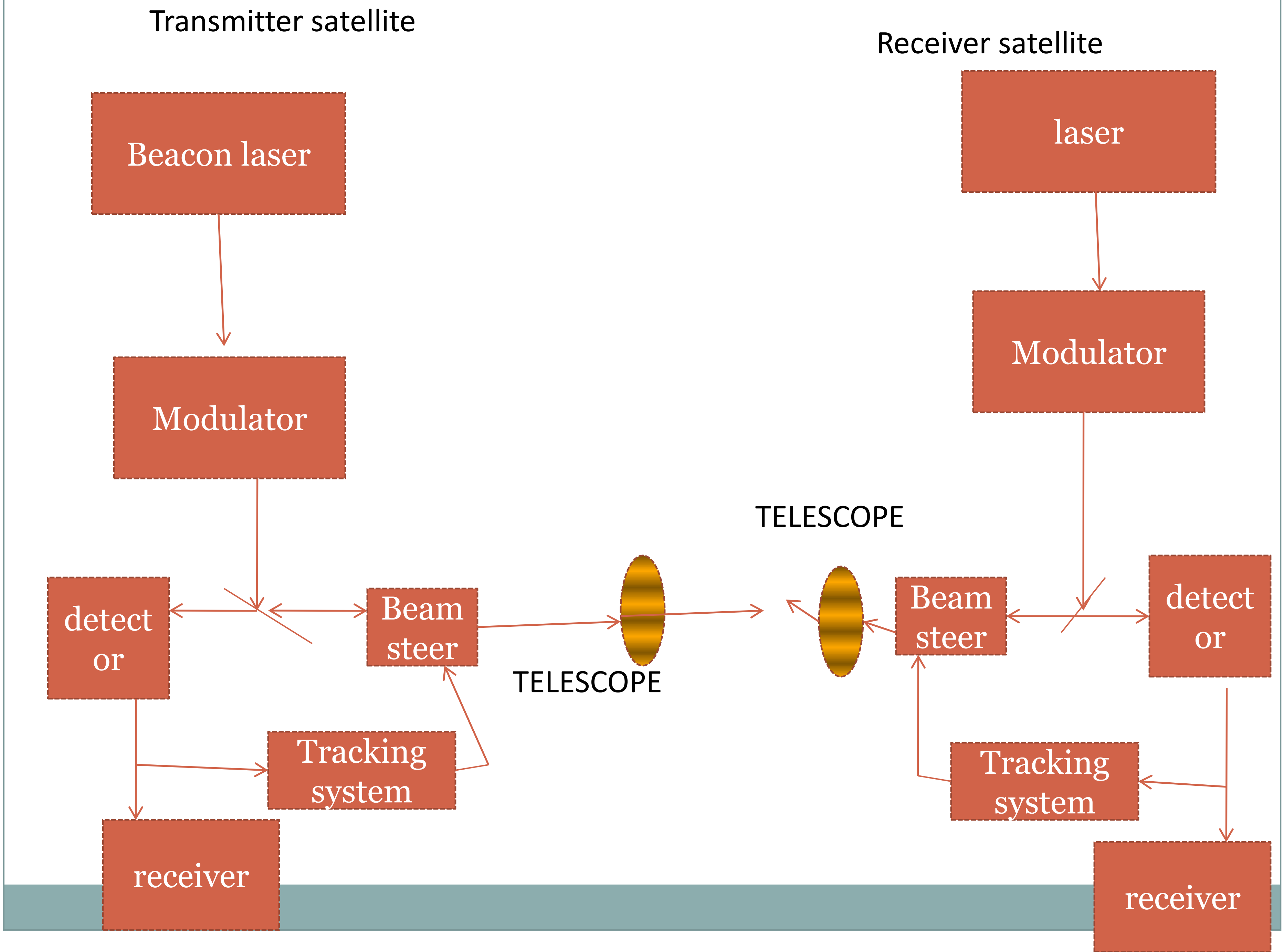
Lecture 22 & 23

PRINCIPLES OF SATELLITE COMMUNICATION



Transmitter satellite
Receiver satellite
Beacon laser
laser
Modulator
Modulator
TELESCOPE
detect or
Beam steer
TELESCOPE
Beam steer
detect or
Tracking system
Tracking system
receiver
receiver

OPTICAL SATELLITE LINK TRANSMITTER

- LASER SOURCE
- MODULATOR
- ANTENNAS

Satellite beam and acquisition, tracking and pointing

- Vt is the tangential velocity of the receiving satellite
- $\alpha = Vt/150$ micro radians
- Point ahead angle exceed the one half of the laser modulated beam width then the use of point ahead angle is made

LASER

- LASER SOURCE:

a. GAS LASER,
b. SOLID STATE LASER,
c. SEMICONDUCTOR LASER

Semiconductor laser

- AlGaAs and InGaAsP are also being used
- AlGaAs is reliable between 0.78 and 0.86 μm
- InGaAsP emits between 1.2 and 1,65 μm
- Lasers diodes are low power devices
- Used in arrays to increase output

LASER
Advantage

- Small size
- Weight
- High efficiency
- Reliability
- Easily modulated

DISADVANTAGE

- Beam combining problem due to limited power per diode.
- Integrated optical technology has developed coherent combining technology
- Increasing the power
- Decreasing the beam divergence

Laser commonly used in satellite communication

LASER TYPE	WAVELENGTH	AVERAGE POWER OUTPUT	EFFICIENCY	CHARACTERISTICS
Nd-YAG	1.06 µ	0.5-1 W	0.5-1%	Requires elaborate modulation equipment, diode or solar pumping 10,000 life hours
Crystal	0.532µ	100MW	0.5-1%	
GaAs	0.8-0.9µ	40MW	5-10%	Life hours 5000 ,reliable, small, rugged, compact, directly and easily modulated Easily combined into arrays

Laser commonly used in satellite communication

LASER TYPE	WAVELENGTH	AVERAGE POWER OUTPUT	EFFICIENCY	CHARACTERISTICS
CO_2(gas laser)	1.06 µ	1-2W	10-15%	Life hours 20,000 used in IR range, detectors are poor, Uses a discharge tube, modulation is difficult
HeNe (Helium – Neon)	0.63µ	10MW	1%	Life hours 50,000.requires external modulation, has gas tube ,is power limited and is inefficient

MODULATORS

- Direct intensity modulation
- Driving current is varied in accordance with the type of modulation

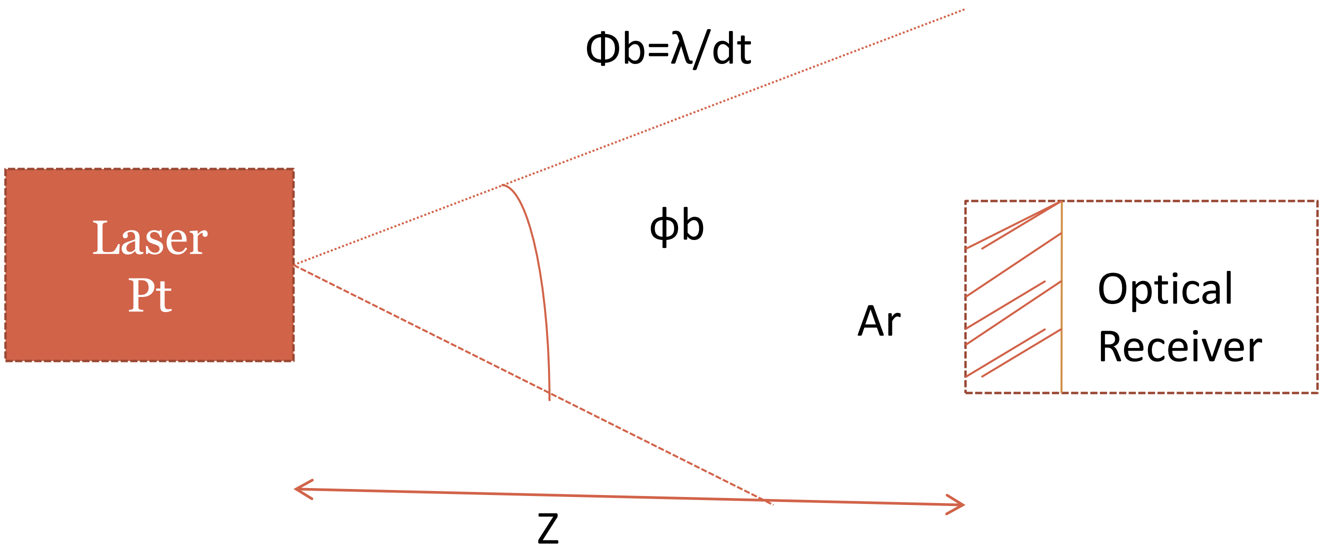
Various optical laser modulation method

Modulation type	Analog	pulse	digital
Information Signal	Time Continuous	Time Continuous Or sampled	Time sampling
Carrier Parameter	Continuous	Continuous Or Quantized	Quantized or coded
Example	Intensity modulation	Pulse intensity modulation	Pulse code modulation, intensity modulation

ANTENNA

- Conventional Telescopes
- Size and geometry – as per the wavelength and geometry
- Narrow light beams
- Lensing system for transmission and focusing

Optical Antenna Transmission



$$P_r = \frac{P_t A_r}{\varphi_b^2 Z^2}$$

$$g_t = \frac{4\pi}{\varphi_b^2}$$

$$L_p \approx \left(4\pi / \lambda Z^2 \right)$$

$$P_r = \frac{P_t (d_t d_r)^2}{\lambda^2 Z^2}$$

$$n_r = \frac{P_r}{h f_o}$$

fo is optical frequency

Nr photo electrons per second

Optical satellite link reciever

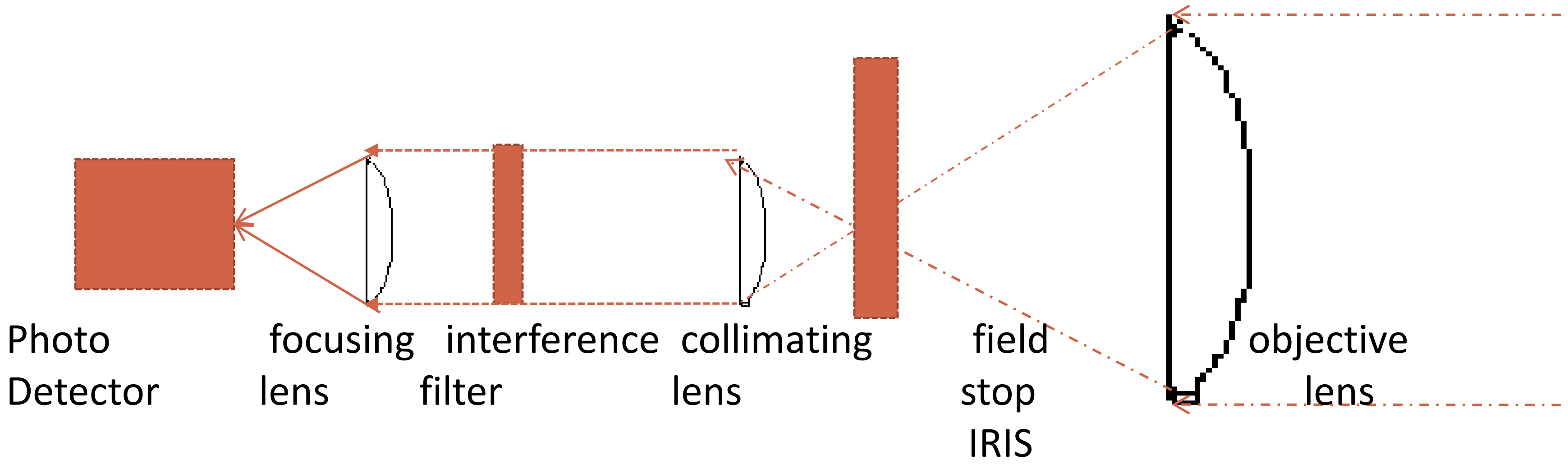
- telescope: focus the optical signal on to the photo detector
- Optical filter: eliminate back ground radiation that is not of same wavelength as the optical signal

Optical detection

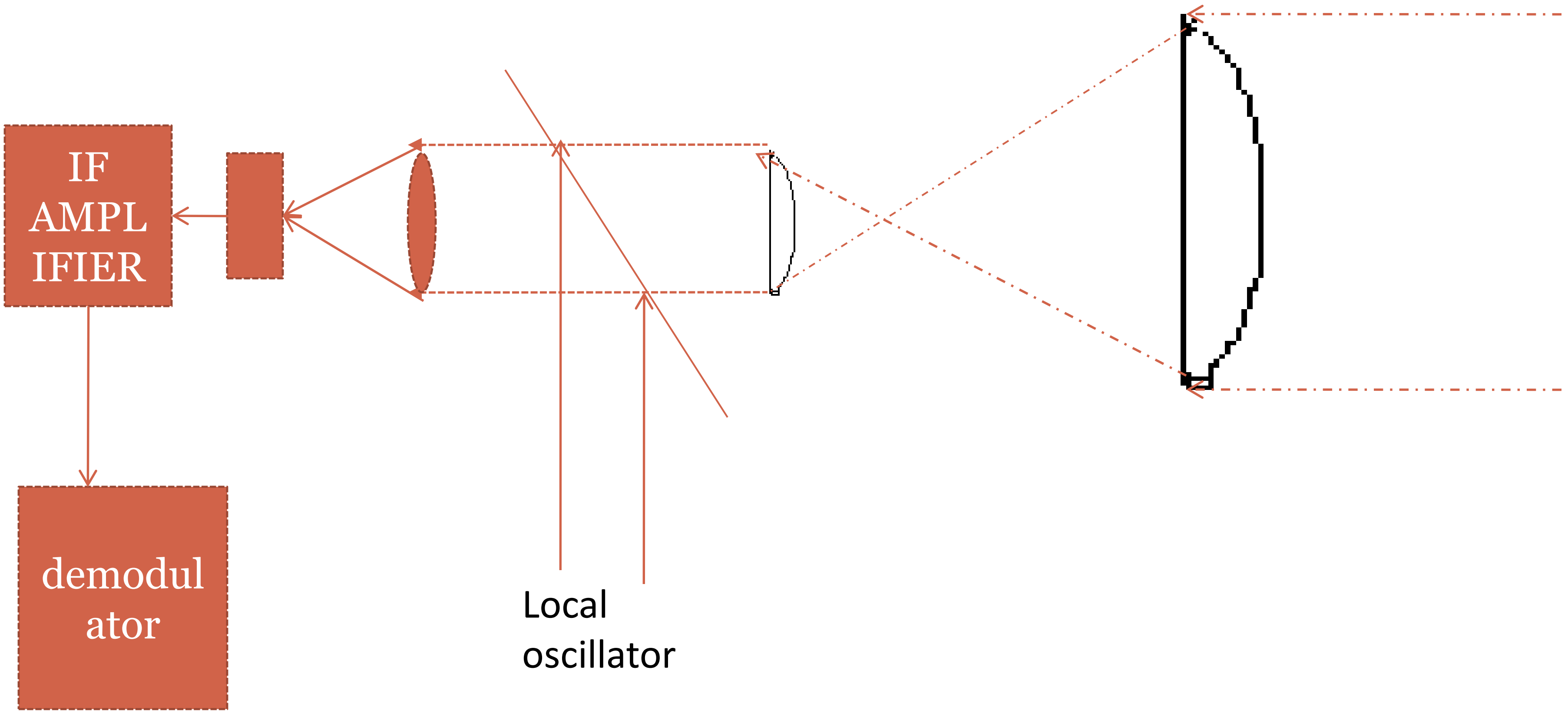
- Direct detection System
- Heterodyne system

Direct Detection System

- Respond to the signal intensity



Principle of heterodyne detection



Heterodyne receiver

- Optical receiver field view:

Field arriving angles over which lenses will focus the impinging field onto the photo detector surface

Detector area and focal length

$\Omega fv = Ad/f^2c = Ad/Ar = (Ad/\lambda^2)(\lambda^2/Ar)$

(λ^2/Ar) diffraction limited field of view

Heterodyne receiver

- P-I-N diode and avalanche photo diode
- Detection efficiency, gain, responsivity and bandwidth
- Wave length dependent, material used for photo emission
- Detected count rate of optical receiver

$N_s=(\eta/hf_o)P_r$

Photo detector

- Gain is increased by cascading photoemissive surface– noise increases
- Excess noise factor $F= 1+\sigma^2_d/(G)^2$
- G mean gain
- σ^2_d gain variance
- Responsivity : current produced for a given output
- $R=e\eta G /hf_o$

Photo detector

- $Ns(w)=G^2 \overline{FeRP}$
- $Ndc(w)=eI_{dc}$
- $Nt(w)= 4KT^o_{eq}/R_L$
- R_L is impedance load
- T^o_{eq} noise equivalent temperature
- Intensity modulation so s(t) information wave form modulated on the laser field
- $Pr(t)= Pr[1+\beta s(t)]$

Photo detector

- After detection photo detector current will be
- $i(t)=R[Pr(t)+Pb]+i_{sn}(t)+i_{dc}(t)+i_{i}(t)$
- $Ps=(RPr\beta)^2$ signal power
- $Pn=N_o\,(2Bm)$ total noise power
- $SNR=Ps/Pn$
- $=(RPr\beta)^2 /[\, G^2\, FeR(Pr+Pb)+ eI_{dc}+ 2KT^{o}_{eq}/R_L]2Bm$