3. Tutorial on Optical Sources and Detectors

May 21st 2012

Problem 1: Wavelength and frequency conversion

Convert the following characteristics as they can be found in the literature (e.g. laser data sheet or ITU-T Recommendation G.694.1). Write down the formulas used for conversion. You can use a calculator however you should remember some order of magnitude estimates!

Characteristic	Converted
Wavelength: 1550 nm	Frequency:
Frequency: 229 THz	Wavelength:
Spectral line width @ center wavelength of 1550 nm: Δf = 1 MHz	$\Delta\lambda$ =
Spectral line width @ center wavelength of 1310 nm: Δf = 1 MHz	$\Delta\lambda$ =
ITU[1] frequency spacing (center frequency 193.1 THz): Δf = 100 GHz	$\Delta\lambda$ =
Resolution bandwidth of an OSA[2] (APEX AP2043B, Span: 1526 nm to 1567 nm): $\Delta\lambda$ = 0.16 pm	Δf =

Problem 2: Erbium doped fiber amplifier

Erbium doped fiber amplifier (EDFA) are widely used devices in optical networks. They consist normally of a single mode fiber which is doped with Erbium, a rare earth element. The fiber is optically pumped with laser diodes at 980 nm or 1480 nm and the resulting gain is used for signal amplification.

a) Typical characteristic data of an EDFA are a spectral width of $\Delta\lambda$ = 50 nm at a center wavelength λ_0 = 1.55 µm and a spontaneous lifetime of τ_{sp} = 10 ms.
   Is the Erbium doped fiber a homogeneously or inhomogeneously broadened gain material? Why?
b) The refractive index of the fiber is n = 1.46. With the given values from a) determine the emission cross section $\sigma(f)$ of the Er^{3+} atom. For simplicity assume that the line shape function has a rectangular shape of area one and spectral width $\Delta\lambda$ as depicted in Fig. 1.

[1] ITU: International Telecommunication Union
[2] OSA: Optical Spectrum Analyzer

c) Take the value for the emission cross section and calculate the population difference N_2-N_1 that is required to achieve 30 dB gain in an EDFA with 30 m of Erbium doped fiber.
d) Why are EDFA so popular in wavelength division multiplexing (WDM) systems?

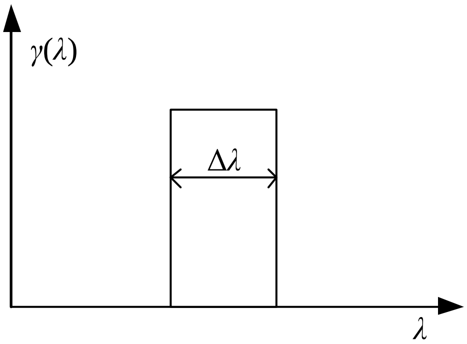

Fig. 1: Simplified line shape function

Problem 3: Transatlantic fiber link

Without optical amplification it is not possible to optically transmit data from London to New York, i.e. 7000 km of fiber length with an attenuation of 0.2 dB/km. Therefore Erbium doped fiber amplifiers (EDFA), which can amplify an optical input signal of –15 dBm to +1 dBm, are employed for a transatlantic fiber link. Assume that the optical transmitter at London is sending with an optical power of +1 dBm and that the receiver at New York is able to detect optical signals down to –35 dBm.

a) How many EDFA are necessary for an optical transatlantic fiber link?
b) Each EDFA needs electrical power supply. Estimate the power consumption of a single EDFA for 8 transmitted channels, if the power efficiency of the EDFA is $\eta = 0.01$ and the power consumption is proportional to the number of transmitted channels. How much is the power consumption for the whole transatlantic fiber link (assume that electrical line losses can be neglected)?

Questions and Comments:

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