ECSE-6660: Broadband Networks

Informal Quiz (SOLUTIONS)

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Reading Assignment & Quick Questions

Reading assignments: carefully review slide sets 11,12; Read Chap 1,2,3 of Ramaswami/Sivarajan's book.

Then answer the following quick true/false questions that test your knowledge.

(Tick (√) the appropriate boxes on the left)

T	F	
☐	√	Optical signals cannot cross each other without distortion
☐	√	TEM waves are characterized by their phase and propagation speed.
☐	√	Different wavelengths of light travel at the same speed in matter
√	☐	Reflectivity affects the polarization but not the phase of reflected optical light
√	☐	The cladding always has a higher refractive index than the core of a fiber
√	☐	Ray optics is the limit of wave optics when the wavelength is very small
☐	√	As a monochromatic light propagates through media having different refractive indices the velocity remains the same however the frequency varies
√	☐	In polychromatic light the diffraction of the light depends on its wavelength
√	☐	Speckle patterns vary rapidly with time however the energy and power are conserved
☐	√	The bit rate achievable in multimode fibers is primarily limited by chromatic dispersion

- ☐ √ Single mode fiber eliminates delay spread from all sources
- √ ☐ Signal degradation due to chromatic dispersion is inversely proportional to the data-rate
- ☐ √ Graded index multimode fibers offer higher bit rates than single mode fibers for shorter distances
- ☐ √ Different spectral components of the same pulse travel at the same speed in single-mode fiber, which is why it is called "single" mode
- √ ☐ Negative pulse chirping worsens the pulse broadening effects
- √ ☐ For certain chirping patterns and GVD parameters the chirped pulses may compress in time, and expand after traveling some distance
- ☐ √ Dispersion shifted fibers help reduce the material dispersion
- ☐ √ Dispersion shifted fiber (DSF) tackle both the chromatic and the non-linear effects like four-wave mixing
- √ ☐ Polarization refers to the direction of the electric field vector
- √ ☐ A birefringent crystal has different refractive indices in different directions
- ☐ √ The pump wave gains power as it propagates in fiber
- ☐ √ In Stimulated Raman Scattering, the Stokes wave is a wave of shorter wavelength propagating only in the reverse direction
- √ ☐ The SRS effect itself can be used to create high powered lasers at an appropriate wavelength from lower wavelengths
- ☐ √ In case of SBS effect, the Stokes wave propagates in the forward direction

- ☐ √ Higher order solitons are family of pulses that undergo no changes in shape as their propagate through fiber
- √ ☐ Solitons are created through the interaction of carefully shaped pulses with fiber effects such as chromatic dispersion and self-phase modulation
- ☐ √ The conservation of energy constraint says that the electric fields at two outputs of an optical coupler cannot have the same magnitude
- ☐ √ Isolators allow bi-directional transmission
- √ ☐ Faraday rotators can rotate the polarization of the incoming light
- √ ☐ Optical Filters are based upon phenomena such as interference or diffraction
- √ ☐ Transmission gratings have narrow slits whereas reflection gratings have narrow reflection surfaces
- √ ☐ Long period fiber gratings are used to provide gain compensation
- ☐ √ Energy after grating interaction is reflected back in the reverse-direction in a Long Period fiber grating
- √ ☐ Fabry - Perot filters are cavity-based devices where the filtering is done by superposition of partially transmitted waves with other partially transmitted waves that are phase shifted due to repeated reflections within the cavity
- ☐ √ An F-P filter with low reflectivity cavity walls is a laser
- √ ☐ TFMF is an FP etalon where mirrors are realized using a multiple reflective dielectric thin-film layers
- √ ☐ In a Mach- Zehnder Inferometer, the light signal is split into copies, and the copies of the signal are phase shifted and combined

- ☐ √ Isolators are in general polarization-independent devices
- √ ☐ Only the wavelength that satisfy the Bragg condition are strongly reflected in a bragg grating
- √ ☐ An apodized Bragg grating would have a significant suppression of sidelobes in the spectral response, but a broader main lobe
- √ ☐ Circulators in combination with Bragg Gratings can be used to construct OADMs
- √ ☐ Chirped fiber bragg gratings can be used to provide compensation for chromatic dispersion, in addition to filtering
- √ ☐ Arrayed waveguide gratings are superior to basic M-Z interferometers for larger-scale multiplexing/demultiplexing operation
- √ ☐ Acousto-optic effects can be used to create tunable filter, or dynamic wavelength cross-connects
- √ ☐ Multi-stage interleaving can be used to build large multiplexors with several components that have only wider spectral responses
- ☐ √ A 3R regeneration device is transparent to electrical modulation characteristics
- √ ☐ A 2R regeneration device is cannot compensate for timing drifts
- √ ☐ An all-optical amplifier is largely transparent to bit rates, number of wavelengths and modulation formats
- ☐ √ An EDFA has a larger gain spectrum than a Raman optical amplifer
- √ ☐ An EDFA has a larger gain coefficient than a Raman optical amplifier
- √ ☐ The EDFA works using the principle of stimulated emission and by creating a population inversion in the appropriate high energy level
- ☐ √ The purpose of the pump laser in both EDFA and Raman amplifier is the same: to create a population inversion at the appropriate high energy level

- ☐ √ Spontaneous emission is called coherent because has the same wavelength as the signal spectrum being amplified in an EDFA
- √ ☐ ASE refers to the noise caused by the amplification of spontaneous emission
- √ ☐ The purpose of erbium ion doping is to create energy bandgaps corresponding to 1550nm using the phenomenon called Stark splitting
- √ ☐ The reason EDFAs have non-uniform gain and amplify a spectrum of wavelengths (rather than a single wavelength) is because there is a some non-uniformity and spread in the ion distribution around the energy levels
- ☐ √ Population inversion refers to the situation where there are more charge carriers in the lower energy level compared to the higher energy level
- √ ☐ Population inversion sets the stage for persistent stimulated emission triggered by the optical signal
- √ ☐ Stimulated emission leads to a charge carrier going from a higher to a lower energy level, and releasing a photon coherent with the stimulating photon
- √ ☐ Longer wavelength correspond to smaller energy photons and smaller bandgap
- ☐ √ The spontaneous emission lifetime at the desired higher energy level (eg: E2 in EDFA fibers) should be extremely short, especially compared to the immediately higher energy level (eg: E3)
- √ ☐ The process of "pumping" in EDFAs is created by a combination of absorption (charge carriers jumping from E1 to E3), short lifetime in E3, release of a phonon to jump from E3 to E2.
- ☐ √ 980 nm pumps can be used remotely, as far as 100 miles away from the amplification site
- √ ☐ Gain flattening in EDFA is done by wavelength-selective attenuation (achieved using components like long-period in-fiber gratings)

√ ☐ Counter pumping refers to pumping in a direction reverse of the flow of information.

√ ☐ Raman amplification in ultra-long-haul systems is done over the lengths of fiber between two EDFAs to complement the gain offered by EDFA

√ ☐ A key difference between mere optical amplification and lasing is the need to develop sufficient positive feedback within the cavity

☐ √ An MLM laser outputs a single longitudinal mode, with a tight spectral width

√ ☐ Wavelength drift in a laser is undesirable because it would be exacerbated by chromatic dispersion and would conflict with tight DWDM channel spacing needs

√ ☐ Unlike LEDs, lasers display a non-linear relationship between drive current and output power

☐ √ Coherence refers to two photons having the same wavelength.

√ ☐ Double heterojunctions are useful to trap a lower bandgap material (where the lasing or LED action takes place) between two higher bandgap materials.

√ ☐ The spectral width (of a laser or LED) is less of an issue in free-space-communications (compared to fiber communications) because the refractive index of atmosphere is close to 1

√ ☐ A laser output power spectrum plot (especially MLM lasers) may have several lines with short line widths that correspond to the various resonant frequencies of the cavity used

√ ☐ An MLM laser may be converted into a SLM laser either by making the cavity length very small (eg: VCSEL design), or by using external cavities or gratings to filter the extra lines.

√ ☐ An index-guided laser better localizes the output power of a laser

☐ √ The word "mode" means the same thing in the context of lasers (eg: MLM vs SLM) and fibers (multimode vs single-mode)

√ ☐ If the bragg gratings are present outside the laser gain region, it is called a DBR laser

√ ☐ VCSELs at long wavelengths (eg: 1550 nm) have been harder to make partly because of heat dissipation issues

√ ☐ VCSELs are easier to manufacture in bulk than regular lasers

√ ☐ Tunability in lasers is achieved by having sections where the gain, phase and filter wavelength may be separately tuned

☐ √ A photo-detector is essentially a positively biased PN junction

√ ☐ A PIN design is superior to a PN design because the intrinsic (I) region can be made larger.

☐ √ Responsivity of detectors in general decreases with increases in wavelength and the quantum efficiency respectively.

√ ☐ A photodiode is more efficient than a photoconductor because fewer electrons recombine into holes after being created by the impinging photon

√ ☐ An avalanche photodiode has a gain region where the electrons are accelerated to knock off other electrons, creating a multiplier effect

☐ √ NRZ modulation requires higher bandwidth than RZ modulation