PHTN1400 Term Test #3 – Study Questions

Sources: From various powerpoints, lectures, student questions, and tutor's questions

Safety

Calculating the required OC of safety glasses
Calculating the power transmitted by a particular set of glasses

Q-Switching

#1: a) If we wanted to replace the 300 line/mm grating in a diffraction-grating spectrometer with an AOM, what RF drive frequency would we use with a TeO2-S AOM (with an acoustic velocity of 650m/s)?

Answer: 195MHz

b) For an AOM, n= 1.46, find the grating spacing produced when this device is operating at 28 MHz if the acoustic velocity through the quartz is 3750 m/s.

Answer: 134E-6m

c) If the laser has an output of 488 nm, calculate the angle of deflection (Bragg).

Answer: 1.82E-3 radians

d) To achieve the same angle of deflection calculate the frequency the AOM needs to operate at when using a HeNe of 632 nm.

Answer: 21.58MHz

Review Lab #5 and the Isomet application note *Bragg Angle Errors* which was required reading for lab #5 and needed to complete the prelab.

#2: Given a laser with parameters as follows:

HR = 99.9999%R	λ = 694.3nm
OC = 90.0%R	n = 1.76
γa = 0.02 cm-1	Lrod = 15 cm

The laser is found to operate when a Pockel's cell (with a half-wave voltage of 8.0kV at 632.8nm and a specified insertion loss from the datasheet of 5.6%) has an applied voltage of 6.5kV. Compute the gain of the laser

Answer: Completed in class in detail including calculations of half-wave voltage, EOM transmission, and gain. See your notes for details

#3: Holdoff Loss

a) A YAG laser is to be used with an AOM Q-Switch. The absorption is assumed to be $0.1m^{-1}$, the rod is given as 10cm long, optics are given as

100% (HR) and 90% (OC). Solve for Tc (Transmission with the Q-Switch when CLOSED) to properly Q-switch this laser. For safety, assume a small-signal gain figure of $10m^{-1}$ (the maximum conceivable).

Answer: Tc=0.39

b) Calculate the required DE for the above AOM switch

Answer: Using the criteria of the Isomet App Note on "Maximizing DE" and assuming a perfect Bragg modulator (with no appreciable orders other than zero and one – see lab #5 results), with the RF signal ON, 61% would be deflected to the first order (and 39% transmitted by zeroth order, this is Tc) so DE is then 0.61

#4: a) Compute the loss that an E/O Q-Switch must introduce into the system in order to properly Q-Switch the following laser.

$\Delta N = 16x10^{24} m^{-3}$	$\sigma = 0.5x10^{-24} m^2$	$\gamma=0.05cm^{-1}$
HR= 99.999%	OC = 89.9%	L_{rod} =17cm
λ=632nm		

Answer: 63.3% transmission

b) The Q-Switch has a half wave voltage of 3.5 kV at 1064 nm with an inserted loss of 1%. Will the Q-Switch introduce enough loss if 3 kV is applied?

Answer: 58.3%, Yes

c) What maximum voltage can be applied to the switch and still prevent the laser from oscillating?

Answer: 1226V

Both parts (b) and (c) are "trick questions"

d) If a Q-Switch introduced a loss of 15% calculate the max population inversion if the laser has an OC of 90% R, HR of 99.999% R. The attenuation of the 12 cm rod is $0.02cm^{-1}$ and the rod diameter is 2cm. The cross section of the lasing ion is $2.5x10^{-23}m^2$.

Answer: 2.75E19 ions … Oops, try T=0.85 for 5.72E18 ions

#5: Prelab #5

Contains an excellent example of how to compute <u>Bragg angle</u> and <u>Separation angle</u> (and the difference between them) as well as AOM alignment

<u>Modelocking</u>

#1: Frequency

A 50cm long laser consists of a 7.5cm long rod (n=1.76) and a 2cm long Q-switch made of quartz (n=1.46) which is placed close to one mirror. Calculate the operating frequency of the modelocker for this laser.

#2: Cavity Length

A modelocked Nd:YAG laser with a 118mm long rod uses a Gooch&Housego model 12080-3-TE modelocker which is constructed of quartz and is 25mm in length. The frequency of operation is 80MHz +/- 150KHz.
Compensating for all optical elements in the laser, what is the RANGE of lengths possible for the entire laser cavity assuming the modelocker can be tuned within the frequency range given.

Answer: 1.6202m to 1.6273m for the "air" part of the cavity PLUS the original AOM and rod elements. At exactly 80MHz, the total length is 1.875m but this includes (0.118*1.82) and (0.025*1.46) so at 80MHz the total length is air (1.62374m) plus the elements for 1.76674m … the OPTICAL length must always be 1.875m.

<u>Non-Linear</u>

#1: Materials

A Q-Switched YAG laser has a rated output of 500mJ with a pulse length of 10ns. The optics consist of a 99.9%R HR, a 90%R OC, and an EOM. The output beam diameter is 3mm.

(a) Compute the irradiance of the output beam

Answer: 0.7E9 W/cm^2

(b) Can KTP (with a rated damage threshold of 1.01GW/cm^2) be used to double the frequency of the output beam? Show mathematically why/why not.

Answer: Yes

(c) What is the maximum power that KTP can handle when used as a frequency doubler in the laser given (i.e. outside the cavity).

Answer: 71.3MW (Intra-cavity)

(d) If the KTP crystal was placed inside the cavity of the same laser as above, what power density would it be subjected to?.

Answer: 1E10W/cm^2

(e) Can the same KTP be used as an intra-cavity doubler? Show mathematically why/why not.

Answer: No (Why Not?: See notes from class)

(f) What type of crystal is required, type 1 or type 2, and explain why.

Answer: Hint – EOM’s are always linearly polarized

#2: n-Wave Mixing

(a) A CO2 laser with an output wavelength of 9.6μm is mixed with a YAG laser with an output wavelength of 1.064μm. Calculate all wavelengths produced by a non-linear mixing process.

Answer: One wavelength is 958nm, one is a longer wavelength

(b) An Nd:YAG laser oscillating on both 1064nm and 1340nm simultaneously (it has enough gain to do this) has an intra-cavity mixing crystal. What is the visible output wavelength produced?

Answer: 593nm. You’ll find this is now a "standard wavelength" for yellow DPSS lasers.

#3: OPO

a) An OPO pumped with a 532nm Q-Switched frequency-doubled YAG laser has a rated output wavelength range of 680nm to 950nm over which the laser is continuously tunable. Compute the wavelength range of the idler.

Answer: 1208nm to 2440nm

b) In theory, what is the maximum and minimum signal wavelength that the above OPO could produce if phase-matching could be achieved at all possible wavelengths?