Semester S1 – Module 3

Module Fundamentals of coherent photonics

TUTORIAL

LASERS_3

MODE LOCK LASER

Exercise 1

We consider a mode lock laser. It delivers pulses of duration Δt = 136 fs at a repetition rate of $\Delta\nu$ = 470 MHz. The average wavelength is λ_0 = 859 nm. The average power measured is P_{out} = 25 mW.

1. Explain a way to obtain this operating mode.
2. Describe the frequency and time characteristics of the laser emission.
3. Determine:
   - the spectral bandwidth of this laser,
   - the optical length of the Fabry Perot cavity,
   - the number of longitudinal modes,
   - the peak power of each pulse.

Exercise 2

Let us consider a laser emitting a spectral line of $\Delta\nu$ (full width at half maximum). The length of the Fabry-Perot cavity is L. The refractive index of the amplifier medium will be neglected. We will consider the case where the loss coefficient is equal to 50% of the maximum of the small signal gain coefficient.

1-a) Calculate the number M of modes that oscillate as a function of $\Delta\nu$ and L. It is assumed that mode m=0 coincides with the central frequency ν_0 of the laser line profile. Give the resonance frequencies ν_m (longitudinal modes of the cavity).

1-b) Assuming that each longitudinal mode is a monochromatic plane wave of frequency ν_m, and amplitude A_m, that propagates along the Oz axis, give the expression of the field (in complex notation) as a function of t and z when the modes are in phase.

1-c) Show that it can be put in the form of $E(z,t)=A(t-\frac{z}{c})e^{j2\pi f_0\left(t-\frac{z}{c}\right)}$

with $A(t-\frac{z}{c})=\sum_{m=-S}^{S}A_m e^{\frac{j2m\pi(t-z/c)}{T}}$ and $T=\frac{2L}{c}$. $M=2S+1$. M=2S+1 : number of longitudinal modes.

2-a) Considering that all modes have the same complex amplitude $A_m=A$, write A(t-z/c) in the form of $A(t-\frac{z}{c})=A\frac{\sin\left(\frac{M\pi(t-z/c)}{T}\right)}{\sin\left(\frac{\pi(t-z/c)}{T}\right)}$.

2-b) Deduce the intensity as a function of z and t. Draw it as a function of t (z=0) and show that it corresponds to a train of pulses of duration $\tau=T/M\approx1/\Delta\nu$, spaced 2L/c.

2-c) The amplifying medium is a crystal of Nd:YAG for which $\Delta\nu=120\text{GHz}$, calculate the pulse duration.
