Generation and Applications of Ultrahigh-Intensity Laser Pulses

Problem Set 5

Non-linear effects and Dispersion

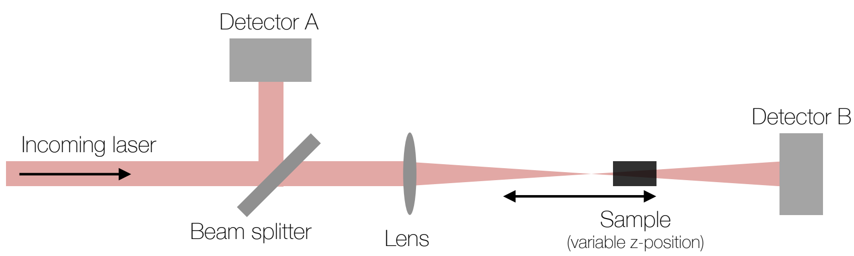
1. Few-cycle pulse generation
Titanium-sapphire lasers are typically limited to a bandwidth of $\lesssim 100\,\mathrm{nm}$.

- Is this bandwidth sufficient to generate pulses with a duration $\Delta t < 10\,\mathrm{fs}$?
- If not, which non-linear effect could be used to broaden the spectrum? Can you think of any effects that limit the input pulse intensity?
- Assuming you have generated a pulse with a gaussian spectrum and a bandwidth limited duration of 10 fs, how does the pulse length change when the pulse passes through a window of 2-mm-thick Sapphire crystal? How can you avoid pulse lengthening?

2. B-Integral in a high-power laser system
Consider a titanium:sapphire high-power laser system with a beam energy of 1 J, a central wavelength of $\lambda = 800\,\mathrm{nm}$ and a gaussian spectrum with $\Delta\lambda = 60\,\mathrm{nm}$. The beam profile is a top-hat with a diameter of 5 cm.

- What is the bandwidth-limited duration of the pulse? Which peak power does the pulse reach?
- Assuming constant intensity over propagation, calculate the distance a perfectly compressed beam can travel in air until a B-integral of unity is reached.
- Calculate the peak power to the critical power for self-focusing in air.
- How does this compare to the case of a pulse that is stretched by introducing a group delay dispersion $D_2 = 1 \times 10^7\,\mathrm{fs}^2$?
- Which optical device would you choose to introduce this amount of group delay dispersion?

3. Z-scan Measurements
A common way to measure the strength of the Kerr non-linearity (i.e. the non-linear refractive index n_2) is the z-scan technique. The method employs an intense laser and two detectors (A and B) to measure the n_2 of a sample which is mounted on a translation stage. The basic setup is sketched below:



Can you figure out how this method might work?

Note: For some exercises you may have to look up the nonlinear refractive index n_2.