Contents

Part I

Optical Coherence Tomography

Chapter 1

Time Domain OCT

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1.1 Theory

In OCT, the kind of interferometry used is the low-coherence type. In this section, we are going to describe how low-coherence interferometry is used to measure the distance of an object with more the one reflecting surface.

1.1.1 Michelson Interferometer

Consider the interferometer shown in figure 1.1.1. To simplify the analisys, ignore the light polarization and dispersion effects. A light source emits a radiation whose electric field shine upon a beamspliter e described by $E_0(t)$. This light is devided and a fraction D of its power is directed

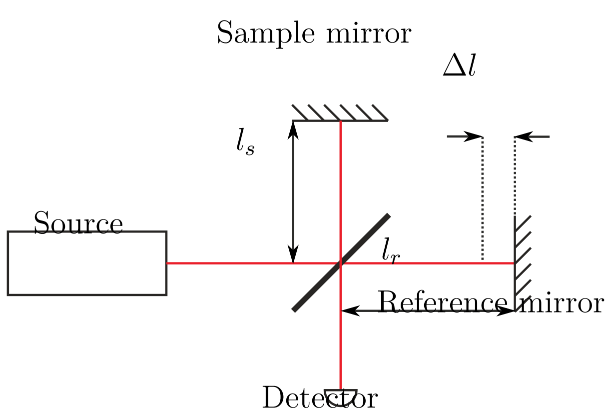

Figure 1.1.1: Michelson interferometer

to mirror S with reflectivity R_s. The light is reflected and returns to the beam spliter, where a fraction $(1-D)$ of its power goes to the detector. Similarly, in the other interferometer arm, $(1-D)$ of the light emited by the light source is redirected to the mirror R_r, which is reflected and returns to the beamspliter, where a fraction D of this light is redirected back to the detector. The electric field at the detector can be decribed by

$$E_s = \sqrt{K_0} E_0 (t - \tau_a) + \sqrt{K_r} E_0 (t - \tau_r), \tag{1.1.1}$$

where $K_i = R_i D (1-D)$ is the light power fraction that is shined to the detector and τ_i is the time the light takes to go from the beamspliter to the mirror i and back.

The relationship between the output light intensity $\langle I \rangle$ and the mean electric field is:

$$\langle I \rangle = \left\langle \frac{|E(t)|^2}{2\eta_0} \right\rangle, \tag{1.1.2}$$

where $\eta_0 = \sqrt{\frac{\mu_0}{\varepsilon_0}}$ is the free space impedance. Using 1.1.1 and 1.1.2, we get the intensity at the detector as been

$$\langle I \rangle = \langle I_{\mathrm{DC}} \rangle + \sqrt{K_s K_r} \Re (\Gamma (\tau_{s,a})) \tag{1.1.3}$$

where $\tau_{r,s} = \tau_s - \tau_r$. We define the autocorrelation function for beam electric field as

$$\Gamma(\tau) = \frac{E(t-\tau) E^*(t)}{\eta_0}$$

and

$$\langle I_{\mathrm{DC}} \rangle = \sum_j K_j \langle I_0 \rangle,$$

where $\langle I_0 \rangle = \left\langle \frac{|E_0(t)|^2}{2\eta_0} \right\rangle$ is the mean light intensity that leaves the source, which in this case is constant. More specifically, it is of interest that the light source should be stationary in the wide sense, which means

1. $\langle E(t) \rangle$ is independent of t.

2. $\langle E(t_1) E^*(t_2) \rangle$ depends only on $\tau = t_2 - t_1$.

1.1.2 Optical interferometry with coherent light

If the light is perfectly coherent (i.e. monochromatic), then its electric field can be described as $E(t) = E_0 e^{-i2\pi\nu t}$ where ν is the optical frequency and E_0 is the field amplitude. Replacing $E(t) = E_0 e^{-i2\pi\nu t}$ in equation and using, we get