A Review of Ultrafast Optics and Optoelectronics

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***Abstract*: - The speed of optoelectronic devices is generally limited by the components which are used on the electronic side of the device. The development of short light pulses from short current pulses, for example, is limited by the speed of an electronic pulse generator. The limitation of the bandwidth of these electronics can be overcome by switching to indirect schemes. These schemes use optical devices, when we have bandwidth problem. This is consisting of very slower optoelectronic technology and the due to the standard optoelectronics. Except from the development of short pulses, we will also use their detection and characterization, their modulation, and transmission effects. These methods help in the functionality of optoelectronics from a temporal resolution of a few picoseconds better into the femtosecond range.**

Keywords: **Femtosecond pulses, ultrafast lasers, pulse characterization, chirped mirrors, dispersion, ultrafast optoelectronics, modulators.**

1.Introduction

Optoelectronics are the electronic devices which are used for emitting, modulating, transmitting or sensing the light. At a very earlier stage, these devices needs interaction of light with an electronic current and converting the photons into electrons or vice versa. The temporal resolution of an optoelectronic emitter is always restricted by the current pulse generator. As like this the detection of light in a photodetector can be see with a temporal resolution of a few picoseconds. Streak cameras, combination of the generation of photoelectrons and their temporal resolution into one device solve the limitations. Even some fastest optoelectronic detected devices are the order of 1ps. In this review we will discuss some ways to ways to electronic bandwidth problem. In early fibre optic data links, light was converted back into an electronic current to any processing. The most improvement in terms of data capacity has been achieved by the method of wavelength-division multiplexing. In this section, we will introduce methods which provide the fundamental optoelectronic functionality of emitting, modulating, transmitting and sensing light with a temporal resolution of a few femtosecond. These are the methods which gives us information for the optoelectronic process into two steps, an ultrafast in all optical step, which gives enough bandwidth, and second is the slow electronic step which allow us good efficiency. Firstly we will discuss about methods for the generation of femtosecond pulses. After that we will discuss the phase and amplitude of femtosecond pulses.

2. Ultrafast laser pulse generation

Laser operation sustained by an optical cavity. This cavity provides the optical feedback. The photons moving in the cavity which gets laser gain and losses happens due to output coupling. In order to generate a short pulse, the energy content of the optical cavity can be confined into as short an interval as possible. It requires to introduce a mechanism short-pulse operation of the laser. This effect reduces the losses of that photons which are travelling synchronously with the help modulator. If electro-optic or acousto-optic modulators are used, this whole scheme is always restricted by the electronic pulses of the modulator. Therefore it is compulsory to eliminate the bandwidth limitation by switching to an all-optical modulator

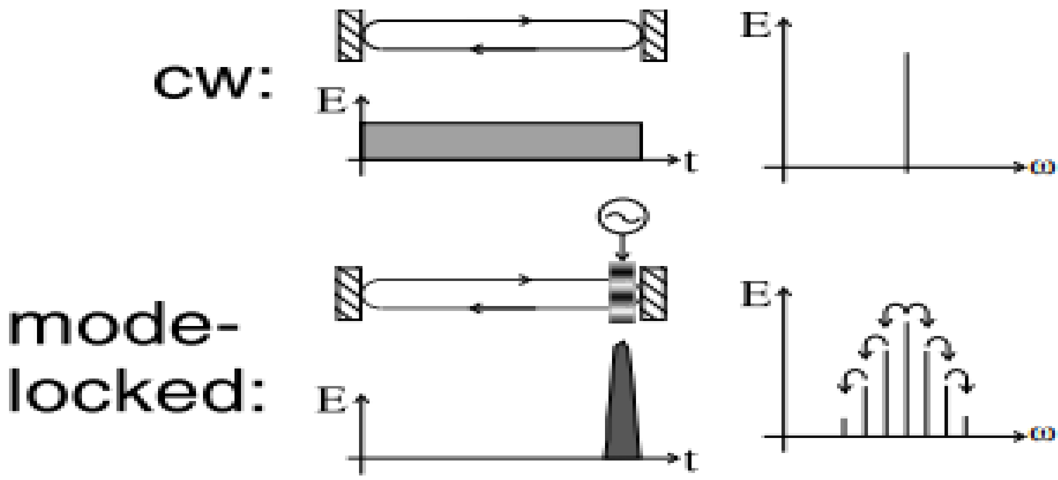

Figure 1. This figure shows the continuous wave and mode-locked (bottom) operation of a laser.

3.Femtosecond pulse propagation effects and dispersion compensation

In electronic systems, a severe limitation is imposed by high-frequency mechanisms. In optics, an absorptive bandwidth limitation is typically not a concern or can be easily avoided. Many dielectric media, such as glasses and crystals, are transparent in the range from 150 to 1000 THz. Limitations typically only arise in optical amplification or nonlinear optical conversion. In a 10 THz window in the near infrared (1.55 µm wavelength), exceptionally low losses of 0.3 dB km−1 have been demonstrated in silica fibres. This ultralow-loss window has received particular attention as it coincides with the amplification band width of Er-doped glass amplifiers which can be easily embedded into optical telecommunication systems. Compared with electronic systems, therefore, optical bandwidth is abundant and a much lesser concern.

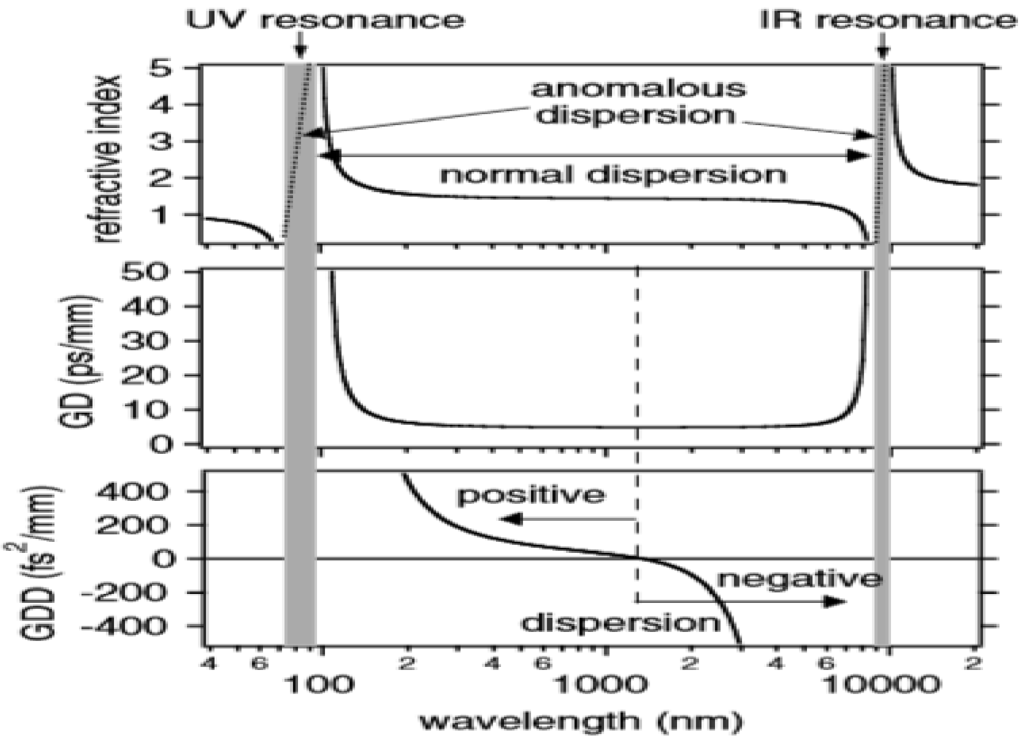

Figure 2. This figure shows the dispersion of a dielectric material.

4.Measurement of optical waveforms with femtosecond resolution

4.1Autocorrelation

Autocorrelation is a time resolved technique in which non linear crystal is required to produce second harmonic generation. There are two types of autocorrelatios, i.e. intensity autocorrelations and interferometric autocorrelations. Both of them have Michelson-type interferometer setup. Intensity autocorrelation uses a transaltion stage scanning the split pulses to give an intensity envelope of the autocorrelation. The pulse width can be deduced from the width of the autocorrelation envelope. Intensity autocorrelation has broad measurement range but it cannot provide complete information about the pulse shape. Interferometric autocorrelation uses a vibratile arm real-time scanning the split pulses to generate a distinctive autocorrelation trace. The chirp and phase of the ultrashort pulse are reflected in the interferometric phase and the vibration range is limited which results in a limitation of measurement range with this technique.

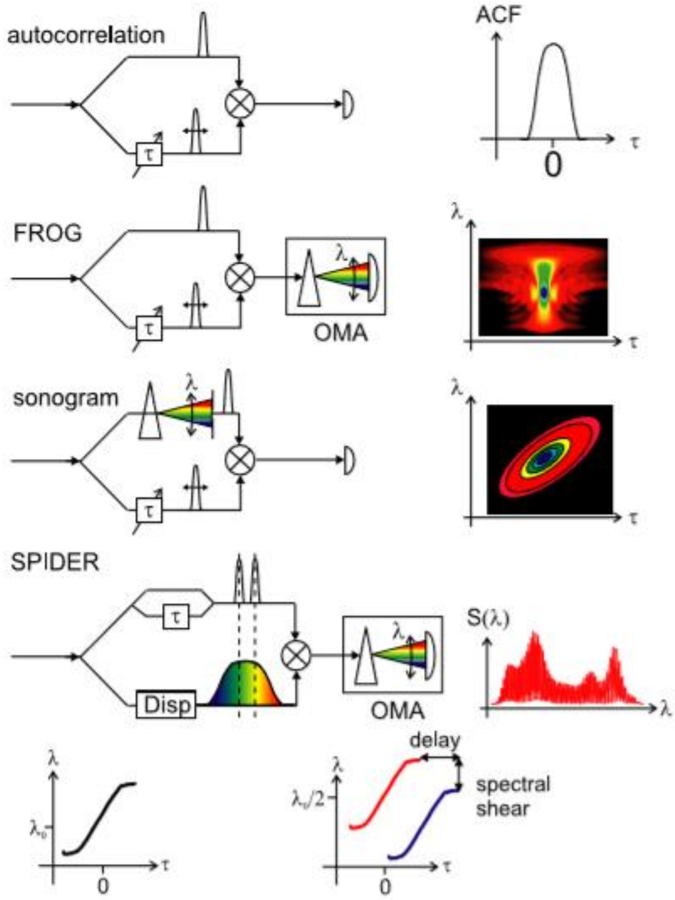

Figure 3. Pulse characterization methods.

4.2 Frequency-Resolved Optical Gating (FROG)

Frequency-resolved optical gating (FROG) is currently the standard technique for measuring the ultrashort laser pulses which replace an older method called autocorrelation. It is invented in 1991 by Rick Trebino and Daniel J. Kane at the Georgia Institute of Technology. There are different version of FROG which generate different kinds of FROG traces and have different strengths and weakness. Polarization-gated FROG (PG FROG), Self-diffraction FROG (SD FROG), Transient-grating FROG (TG FROG), Second-harmonic generation FROG (SHG FROG), Interferometric FROG (IFFROG). Beyond these techniques Second Harmonic Generation FROG is most popular spectrometer-less Frequency-resolved optical gating method.

4.3Spectral phase interferometry for direct electric-field reconstruction (SPIDER)

SPIDER is the another technique to measure ultrashort pulses. It is developed by Chris Iaconis and Ian Walmsley. It implements spectral shearing interferometry using nonlinear optics. It yields extremely short pulses independent of the pulse complexity and instability.

5. Summary

In this review, we have highlighted methods to circumvent the omnipresent electronic bandwidth limitation in optoelectronics. The methods described allow for the generation and the characterization of optical pulses much shorter than a picosecond.

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