SUMMARY OF THE PHD THESIS

NEW RESULTS ACHIEVED UPON THE CONSTRUCTION OF THE FEMTOSECOND TITANIUM-SAPPHIRE LASER SYSTEM AT UNIVERSITY OF SZEGED

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I. PRELIMINARIES AND GOALS

Someone who try to build an amplified femtosecond titanium-sapphire laser system could face a lot of problems. Some of the problems have known solutions but some have not. I have been working on a terawatt peak power laser called TeWaTi (Fig. 1) in the Department of Optics, University of Szeged. I summarize here the work I have done with this laser and related topics.

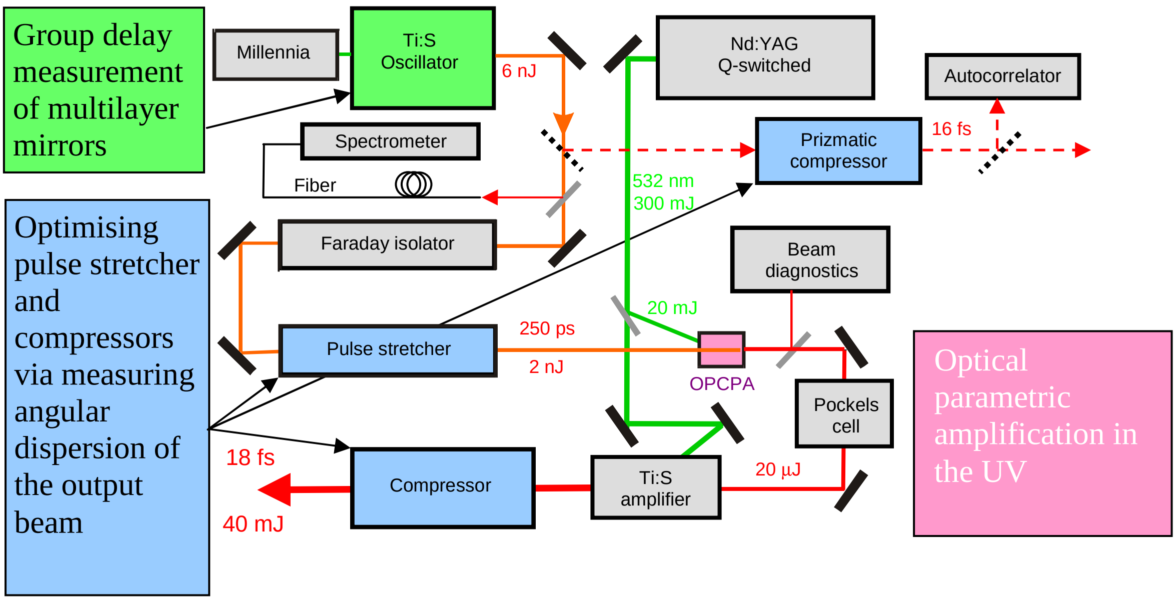

Fig. 1

Block diagram of the TeWaTi laser system.

Mirror Beamspliter Alternate beam path

(for measurements using unamplified pulses)

1. As become known in the early days of femtosecond lasers, the group delay dispersion of multilayer mirrors has an effect on the duration and the phase structure of ultrashort pulses. Specially designed high reflectivity laser mirrors have proved to be good candidates for controlling both intracavity and extracavity group delay dispersion (GDD) in femtosecond lasers. For building a mirror-dispersion-compensated femtosecond oscillator, the GDD of these mirrors has to be precisely known. My first goal is to develop a new

measurement technique for determining group delay and GDD of multilayer dielectric mirrors.

2. Much interest in the generation of white light sources has centred around the use of self phase modulation of femtosecond high intensity laser pulses in ordinary materials as water or fused silica. There are number of applications, especially in spectroscopy and interferometry, which need high brightness incoherent broadband radiation only from much less complicated equipment. My second goal is to demonstrate broadband fluorescence radiation from a multi-component organic dye solution.

3. It is well known that a misaligned stretcher or compressor in a chirped pulse amplification (CPA) laser introduce residual angular dispersion in the beam, which results in spatial-temporal distortion of the pulse, such as pulse-front tilt, spatial and also temporal chirp. The term „angular dispersion" is, however, ambiguously defined in the literature. One definition uses the angle between the propagation directions of different spectral components. The other definition is based on the angle between the phase fronts of the components. For plane waves the two quantities are identical. My third goal is to develop a technique for measuring angular dispersion defined by the first way and using it to optimize the alignment of a stretcher or a compressor of a CPA laser.

4. For spatially Gaussian beams, however, where the phase fronts are curved, the two above mentioned definitions of angular dispersion result in different values. My aims are to calculate parameters of an angularly dispersed Gaussian beam, to develop a technique for measuring phase front angular dispersion and using it to verify the new expressions.

5. The most common ways of generating energetic femtosecond UV pulses shorter than 100 fs are nonlinear frequency conversion of high power VIS-IR pulses, that is second harmonic and sum frequency generation, or direct amplification of short (stretched) seed pulses to high intensity level. The first approach suffers from dispersion and related problems in nonlinear crystals, while the second approach is restricted by either the bandwidth of the readily available high gain excimer amplifiers or the small gain of the relatively broadband newly developed solid state materials. My fifth goal is to investigate the possibility of amplifying femtosecond UV pulses via optical parametric process.

II. METHODS OF INVESTIGATION

1. The measurement of GD of dielectric mirrors was carried out by determining the wavelengths of the transmission maxima of a Fabry-Perot interferometer formed by the mirrors in question. The interferometer was lit by a tungsten halogen lamp and the spectrum of the transmitted light was resolved by a DSF-8 spectrograph and was recorded on a photographic sheet film. The spectrum was evaluated using a Zeiss made comparator.

2. The fluorescence spectrum of the multi-component laser dye solution excited by a Spectra-Physics Ar^+ laser beam was recorded using a Jobin-Yvon H20UV monochromator. It’s power was measured by a power meter from Laser Precision Corp.

3. The angular dispersion, defined using the angle between the propagation direction of different spectral components, was measured by a home made imaging spectrograph. The spectrum was monitored in real time using a CCD detector made by Electrim Corp., connected to a computer.

4. The angular dispersion, defined using the angle between the phase fronts of different spectral components, was measured by a spectrally resolved inverted sides (SRIS) interferometer. The interference fringes at the output of this modified Mach-Zehnder type interferometer was resolved using a home made spectrograph.

5. The chirped pulse amplification scheme was used to achieve high gain noncollinear optical parametric amplification in the UV spectral range. The pulses of an amplified titanium-sapphire laser was split into two parts to produce both signal and pump pulses via SHG and THG respectively. The spectrum of the 800 and 400 nm pulses were measured by an ORIEL MS257 imaging spectrograph using different gratings. The spectrum of the 267 nm pulses were measured by a home made spectrograph. The pulse durations were determined using multiple shot auto- and crosscorrelation. The pulse energies were monitored by a Molectron energy probe or by a calibrated photodiode.

III. RESULTS

1. I have developed a new and simple method to measure group delay and group delay dispersion of mirrors [1, 6-7]. The precision of the measurement demonstrating the technique was 0.24 fs. I have shown that group index of transparent materials can be measured in the same way.

2. I have developed a high brightness, continuous wave, broadband light source based on tight focusing of an Ar^+ laser beam into a properly chosen mixture of laser dyes [8-9]. Two solution was investigated, top-hat spectra was achieved with 161 nm and 131 nm bandwidth. The brightness was 510 times and 1740 times larger than a tungsten halogen lamp.

3. I have used an imaging spectrograph to measure angular dispersion defined using the angle between the propagation direction of different spectral components and to prove the validity of the 3 dimensional analysis describing a misaligned grating compressor. The angular dispersion values calculated using this theory have found to be in good agreement with the experiment [2, 10]. A misaligned prismatic compressor was also investigated in a similarly successful way. The sensitivity of the measurement was 0.2 μrad/nm.

4. I have suggested a measurement setup for angular dispersion defined using the angle between the phase fronts of different spectral components. To demonstrate the method I have measured the angular dispersion caused by a fused silica prism as a function of the incident angle, the distance between the prism and the beam waist and the distance between the prism and the output plane of the interferometer [3-4, 11-12]. The agreement between the results of the measurement and theory is remarkable.

5. As far as I know, I have demonstrated parametric amplification at the UV spectral range for the first time [5, 13-15]. The bandwidth of the amplified pulses have supported 32.4 fs pulse length at 400 nm, supposing perfect compression. The maximum achieved gain was 3550. These numbers are not the ultimate limits of the amplification process but the actual experiment.

IV. PUBLICATIONS

In referred journals:

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