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Different Wavelength Femtosecond Laser Pulses Generated by Diode Pumped Ti: Sapphire Crystal

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Abstract: The relation between the output power and wavelengths for a 532nm 3W frequency doubled diode pumped solid state laser pumped Ti:Sapphire crystal is investigated. A 20 femtosecond pulse at 800 nm is obtained. A 320 mW is found to be the highest power at 800nm. Below this wavelength value and above the power was found to deviate from highest output value.

Introduction

Femtosecond pulses with energies in the milli-joule range are useful for laser micromachining, microsurgery, and spectroscopy [1,2]. The femtosecond pulses generation in the laser cavity requires operation in the negative group delay dispersion GDD regime of the laser cavity, where soliton-like pulses can be formed. The most common way to provide negative dispersion in a cavity is to insert a prism pair [3]. Femtosecond pulses have been obtained only from Ti:sapphire lasers [2,3] which, however, rely on bulky inefficient argon-ion lasers or on expensive frequency-doubled diode-pumped pump lasers. [4] Remarkable progress in the generation of femtosecond pulses with solid state lasers has followed from the discovery of self-mode-locking in a Ti: sapphire laser by Sibbett group in 1991 [5].

Explained as a consequence of self-focusing inside the laser [6], this self-mode-locking behavior has become known as Kerr-lens mode locking (KLM). It is now the basis for femtosecond pulse generation in a wide variety of other solid-state laser systems as well. Self-focusing in the KLM laser in the presence of aperturing due either to the size of the gain spot or some other physically introduced aperture can cause pulse shortening in precisely the manner described by “fast saturable absorber” mode-locking theory [7]. In addition, simultaneously occurring self-phase modulation (SPM), in the presence of group-velocity dispersion (GVD) in the resonator, provides a strong soliton like shaping to the pulses. This latter process can, in fact, be the dominant pulse-shaping effect; however, the KLM remains necessary to suppress the growth of noise between the pulses, thereby stabilizing the mode locking. An important variant of soliton shaping occurs when the GVD alternates between positive and negative values as the pulse propagates. The result can be the formation of “dispersion-managed solitons” even when the average GVD in the resonator is zero or less than the minimum noise to signal ratio [8,9]. Such dispersion management has found important application in “stretched-pulse” fiber lasers [10] and may also play a role in very short pulse Ti: sapphire lasers [11].The present work objective is to investigate the condition regarding the maximum output power for minimum pulse duration (20) fs at different wavelength.

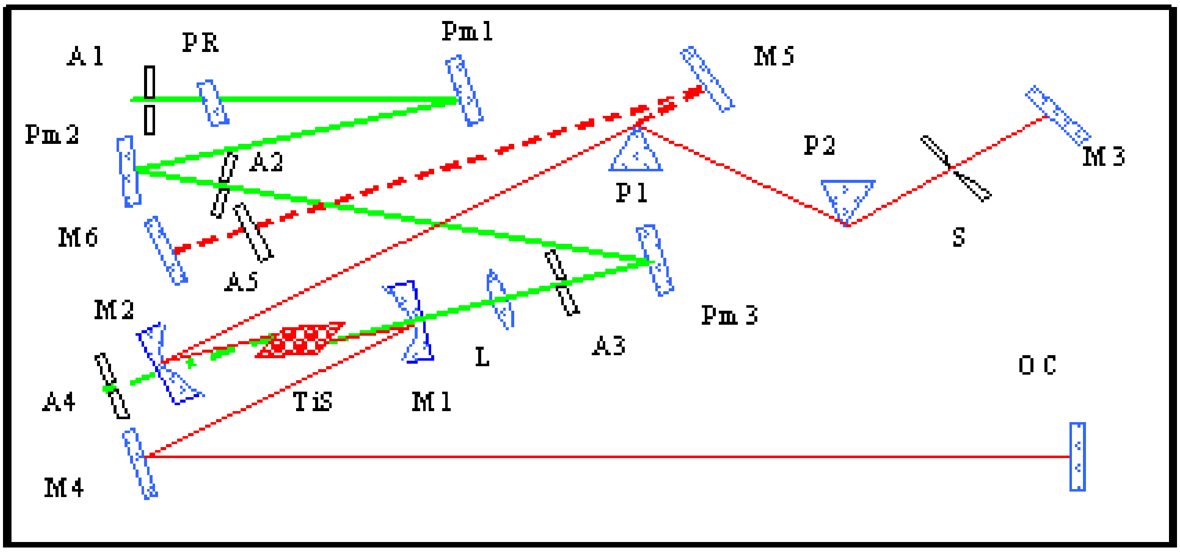


Fig. 1: The experimental set up

A1-A5: Apertures, **M1-M6:** Mirrors for working wavelength, **P1-P2**:- Prism, **Pm1-Pm3:** Mirrors for pumping wavelength, **S**:-slit, **TiS**: Active medium (Ti:Sapphire), **OC**: Output coupler mirror

Experimental Details

Figure 1 shows schematically the system components as indicated. The system involves a 10 mm long Ti-doped sapphire crystal (TiS) as a main lasing medium and dielectric mirrors M1 - M6 with high reflection (>99,5%). M1, M2 – have high reflection for working wavelength and transparent for laser pumping radiation, radius of curvature is 100 mm; M3, M4, M5, M6 - high reflectors for working wavelength, flat mirrors; OC output coupler; Pm1, Pm2, Pm3 – pump routing flat mirrors. L is a - lens for focusing of pumping radiation, focal length is F=100 mm. P1, P2 - Brewster angle prisms at 800 nm.

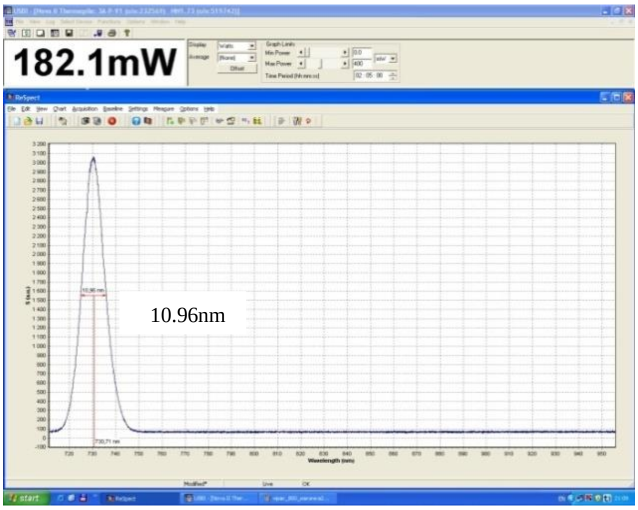
PR – polarization rotator is used for changing the polarization of pump beam from vertical to horizontal. A frequency doubled diode pumped solid state laser(FD-DPSSL) (532nm, 3W) is used as a pumping source (laser quantum Inc.UK) for the Ti-sapphire crystal. The results obtained using a spectrophotometer (ASP 100) which is connected to the PC computer used for monitoring the wavelength. Autocorreator model AA10DM is used to calculate the pulse duration of the pulse.

The laser system is wavelength tuned using a prism sequence and a slit. This sequence provides a region in the cavity where the wavelengths are spatially spread. A variable slit is located in this dispersed beam.

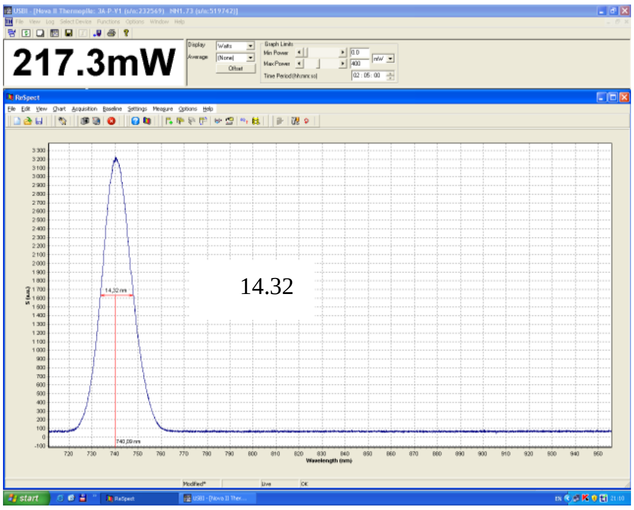
The output wavelength is tuned by changing the position of the slit in the horizontal plane. The width of the slit can also be changed so that the bandwidth (and, hence, the temporal width) of the output pulse can be varied. This simple, straight-forward method covers the entire Ti:sapphire range for ultrashort pulses.

The pulse width tuning characteristics of the Ti:sapphire laser are influenced by two factors: those inherent in the Ti: sapphire material itself and those from cavity parameters. Further pulse spreading causes self-Phase modulation (SPM) in the Ti:sapphire rod, which results from the interaction of the short optical pulse with the nonlinear refractive index. In order to obtain stable short output pulses, these effects must be compensated with negative GVD.

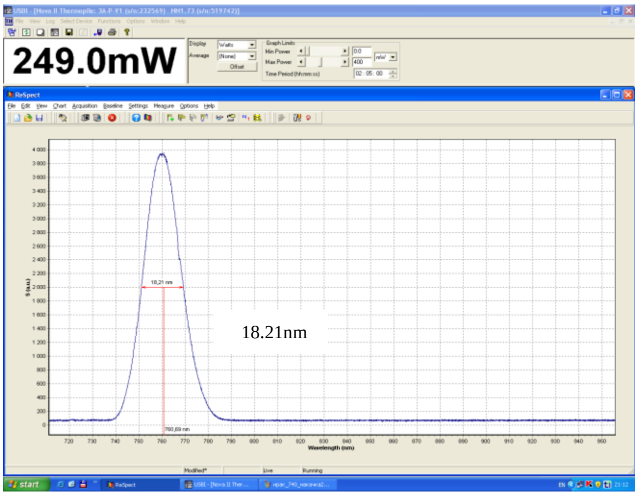
Prism pairs are used to produce a net negative intracavity GVD in the femtosecond system. This allows the system to produce sub 100 fs near transform limited pulses over most of the wavelength regime. Figure 2 shows bandwidth of the output pulse as a function of wavelength. The shorter pulses (the wider bandwidth) are obtained at 800 nm to be 20 fs while it is increase with other wavelength.


182.1mW
10.96nm

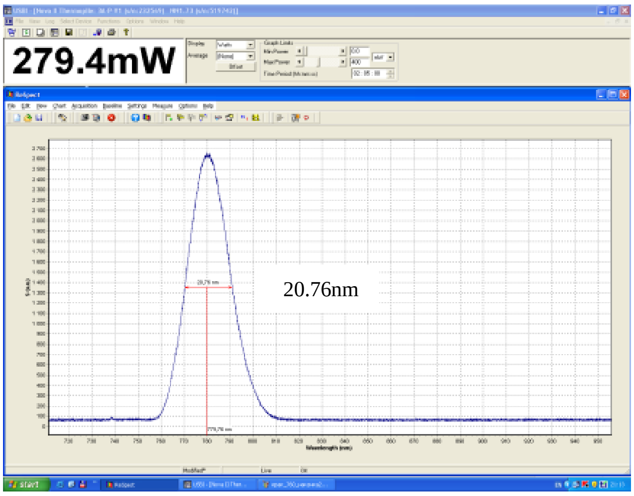
(a)


217.3mW
14.32

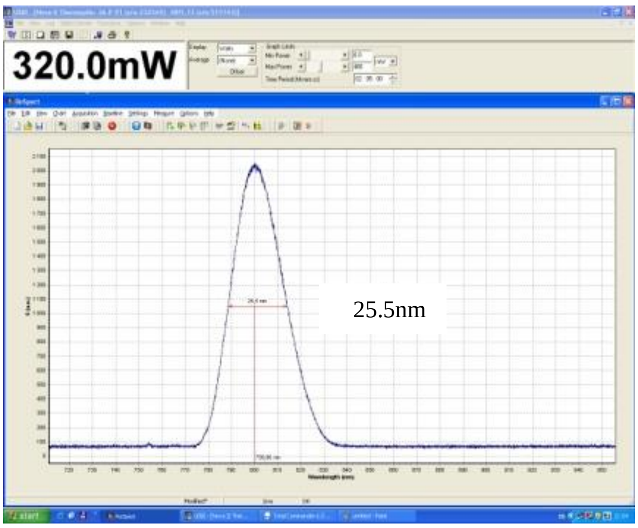
(b)


249.0mW
18.21nm

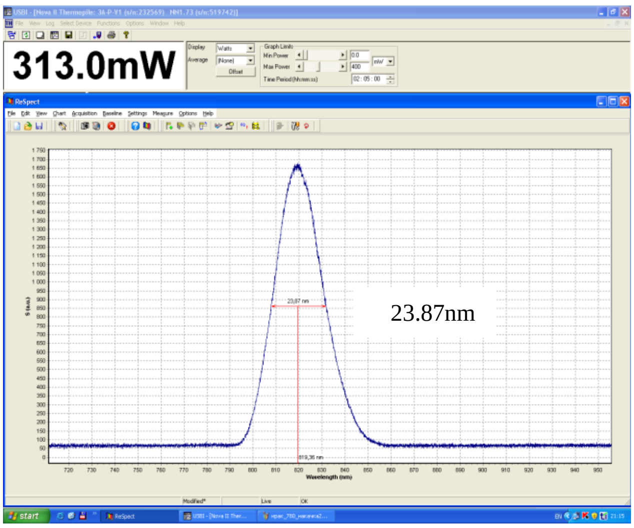
(c)


279.4mW
20.76nm

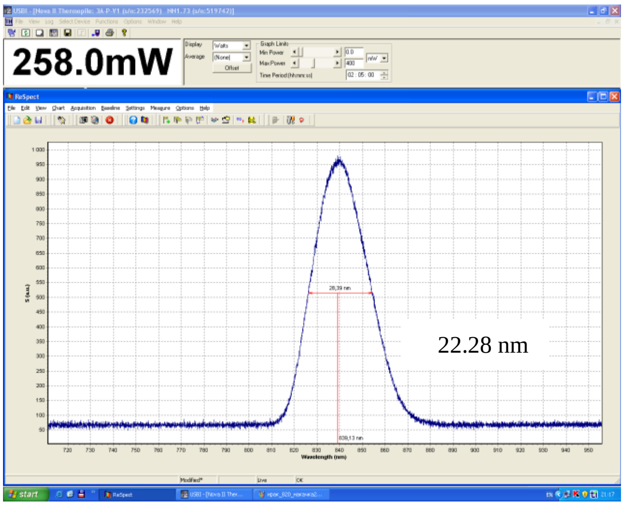
(d)


320.0mW
25.5nm

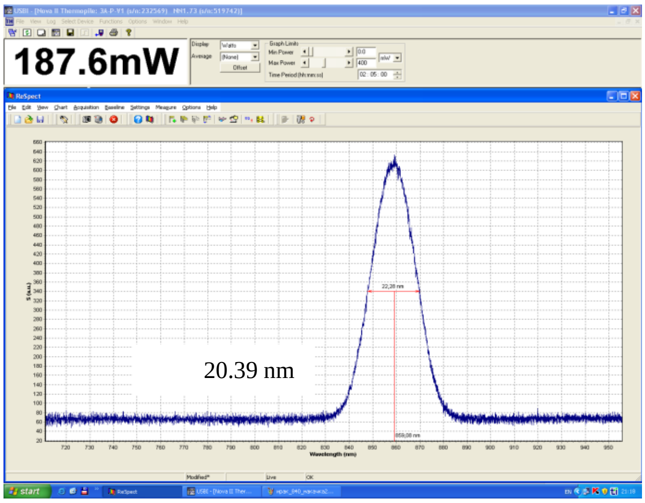
(e)


313.0mW
23.87nm

(f)



(g)



(h)

Fig. (2): The laser output laser pulse at different wavelength a) at 730nm b) at 740 nm c) at 760 nm d)at 780nm e) at 800 nm f) at 820nm g) at 840nm h)at 860.

Figure 3 shows the relation between the laser outputs in mW as a function of the laser output wavelength, the highest power is at 800nm. Fig.4 shows the changes in bandwidth as a function of wavelength. It is clear that the wider bandwidth (the shorter pulse) is at 800nm which is equal to 20 fs.

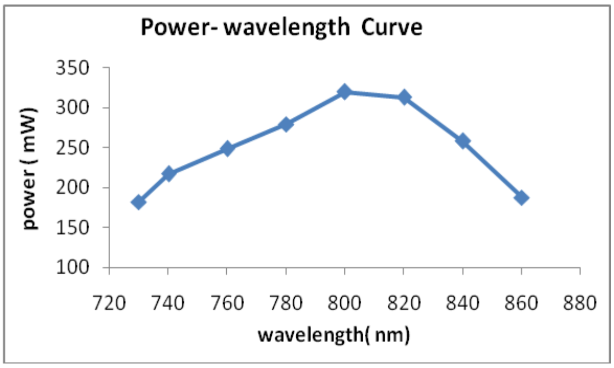


Fig. (3): The output power as a function of output laser wavelength.

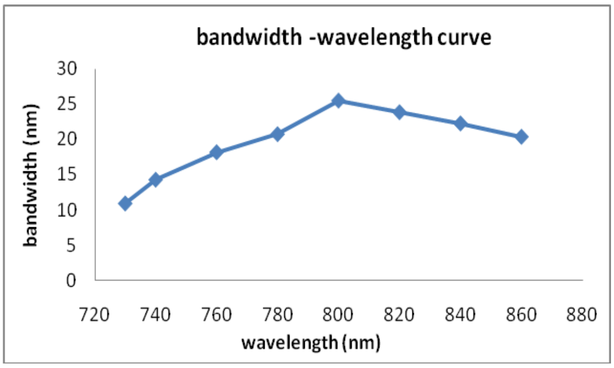


Fig. (4): The pulse bandwidth as a function of wavelength

Conclusion

The pulse duration and the output power are observed to be wavelength dependent. The behavior shows optimum output power to be 320 mW with pulse duration 20fs at 800 nm. It is obvious that the peak absorption wavelength for the active medium leads to butter performance. The absorption peaks spectra of the Ti:Sapphire is at 800nm.

Acknowledgment

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توليد نبضات ليزر ذات أطوال موجية مختلفة باستخدام ليزر الدايود المضخم ببلورة الياقوت

(Ti: Sapphire Crystal)

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الخلاصة

في هذا البحث تمت دراسة العلاقة بين قيمة الخرج الليزري لبلورة Ti :Sapphire المضخة بليزر الثنائي الضوئي ذو التردد المضاعف بطول موجي 532nm وبقدرة 3W . تم الحصول على نبضة بحدود 20fs عند الطول الموجي 800nm ووجد ان اعلى قدرة خرج هي 320 mW عند نفس الطول الموجي وان قيمة القدرة تنحرف قبل وبعد قيمة الطول الموجي عن اعلى مستوى لها.