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Frequency mixing of dual excitation pulses from Ti:Al_2O_3 lasers

Satoshi Wada, Kazuyuki Akagawa*, Akira Suda,
Akira Nakamura*, and Hideo Tashiro

The Institute of Physical and Chemical Research (RIKEN),
2-1 Hirosawa, wako-shi, Saitama, 351-01 Japan
Phone+81-48-462-1111 ex.4423 Fax +81-48-462-4682

*Department of Applied Physics, Science University of Tokyo, 1-3,
Kagurazaka, Shinjuku-ku, Tokyo 162, Japan
Phone+81-3-3260-4271

1.Introduction

Frequency mixing (FM) in the nonlinear crystals is one of attractive methods to extend the tuning range of the lasers. In the ns-pulse operation, dye lasers and their excitation lasers were mainly used as pumping sources so far. Recently, development of tunable solid state lasers allows to apply them to many fields instead of dye lasers [1,2]. For the excitation of frequency mixing, however, synchronization of two excitation pulses for FM is difficult because of wide variation in the pulse bulid-up time with tuning of wavelength, compared with the dye lasers. For example of ns-pulsed Ti:Al_2O_3 lasers pumped with SH of Nd: YAG lasers, the build-up time varies from several tens of nano-second to several hundreds of nano-second[3].

In this work, we have developed a pulsed Ti:Al_2O_3 laser system pumped with SH of a Nd:YAG laser for frequency mixing, which generates two synchronized pulses from two oscillaters. The synchronization of two pulses was performed by controlling of excitation energy of the oscillators. The laser system was successfully applied to difference frequency mixing (DFM) in a BBO crystal. The phase matching conditions with pumping of the Ti:Al_2O_3 laser system were calculated for DFM in the BBO, $AgGaS_2$ and $AgGaSe_2$ crystals. The calculated results show that the wide tuning range from 200 nm to 18 μm can be obtained with the Ti:Al_2O_3 laser system and its wave conversion.

2.Calculation of the phase matching conditions

First, we have calculated the Type-I phase matching conditions for difference frequency mixing of SH and fundamental of Ti:Al_2O_3 lasers in the BBO crystal (q=34.5 degree). Figure 1 shows the relation of output wavelength and pump wavelength. In this calculations, the tuning ranges of pump 1 (SH) and pump 2 (fundamental) were assumed to be from 340 nm to 550 nm and from 680 nm to 1100 nm, respectively. As shown in

Fig. 1, the generated pulses by DFM can be tuned from 500 nm to 750 nm without angle tuning of the BBO crystal. The phase matching conditions for $AgGaS_2$, $AgGaSe_2$ were also calculated. Results were summarized in Fig. 2. It is found that broadly tunable radiation from 200 nm to 18 μm can be obtained from the $Ti:Al_2O_3$ laser system and its converted pulses.

3.Experimental apparatus

Schematic diagram of a $Ti:Al_2O_3$ laser system shown in Fig.3. The SH of a Nd:YAG laser (SP GCR-170) were separated to two beams and each of them excited a Ti:Al2O3 oscillator (Solar CF-131). The energy ratio of two beams was controlled by a half -wave plate and a polarization beam splitter. By changing the energy ratio, two pulses from $Ti:Al_2O_3$ oscillators were synchronized because the pulse build-up time in the oscillator is changed with changing of excitation energy of the Ti: Al_2O_3 crystal. A oscillator in the $Ti:Al_2O_3$ laser system consists of an output-coupler, a holografic grating as a rear reflector, a prism telescope and a brewster-cut $Ti:Al_2O_3$ crystal. The tuning of the output wavelength was performed by rotating of the holographic grating. Typical tuning range was from 680 nm to 950 nm with two types of holographic gratings. The spectral width of a generated pulse was less than 8 pm. Efficiency from SH of the Nd: YAG laser to fundamental of the $Ti:Al_2O_3$ was 20 % at the gain center of $Ti:Al_2O_3$. One of output pulses from the $Ti:Al_2O_3$ laser was converted into SH in a KDP crystal. SH and fundamental were introduced to a BBO crystal that was cut q=34, f=0 for DFM. Output pulses from the BBO crystal were separated to various wavelength components by a prism and each of them was detected by a photodiode and a piro-energy monitor.

3.Result

We measured dependence of the pulse build-up time of the $Ti:Al_2O_3$ laser on pumping energy at various wavelengths. From the results, we found that synchronization is possible at whole tuning range of the $Ti:Al_2O_3$ laser. For example, we set output wavelengths of two oscillators to 710 nm and 809 nm, and chose 150 ns as the pulse build-up time of two pulses. In this condition, the excitation energies of two oscillators set to 710 and 809 nm was automatically decided to 170 mJ and 80 mJ, respectively. Figure 4 shows typical temporal pulse shapes of SH at 355 nm and fundamental at 809 nm of the $Ti:Al_2O_3$ lasers. The synchronization of two pulses was confirmed from this figure. The jitter for two peaks of output pulses was $\pm$ 8 ns. By using these pulses, generation of DFM in the BBO crystal was performed. As a result, we obtained output pulses with tuning range from 580 nm to 700 nm by DFM.

4.Summary

We have developed the $Ti:Al_2O_3$ lasers system pumped with SH of a Nd:YAG laser. This laser system generated two synchronized pulses with different wavelengths. These pulses were used for DFM in the BBO crystal (q=34.5). Tuning range for DFM without angle tuning of the crystals was from 580 nm to 700 nm. The phase matching conditions for DFM in AgGaS2 and AgGaSe2 were also calculated with pumping of the Ti: Al_2O_3 laser system. The result shows that tuning range from 200 nm to 18 μm can be obtained with three kind of the nonlinear crystals. It is noteworthy that such $Ti:Al_2O_3$ laser system with two beams is also applied to DIAL for water vapor and so on.

In the presentation, detail of our lasers system such as the jitter of two pulses, stability of the generated pulses by DFM and so on will be discused.

References

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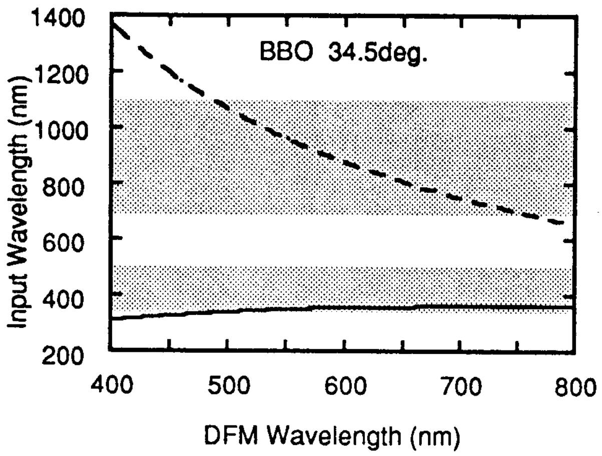

Fig. 1 Type-I phase matching conditions for DFM in the BBO crystal.

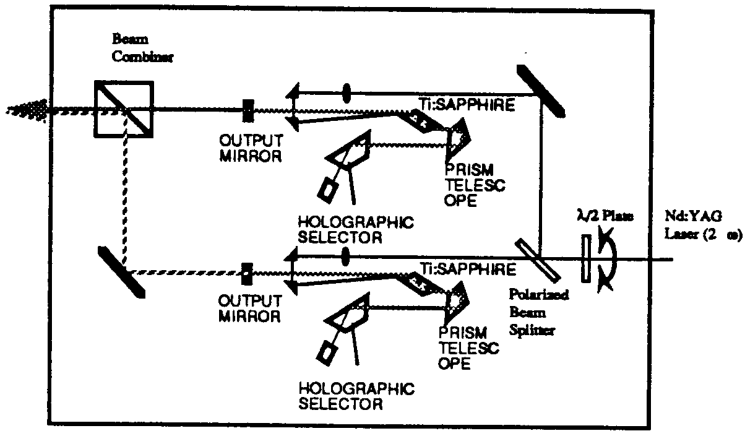

Fig. 3 Schematic diagram of the Ti:Al_2O_3 laser system.

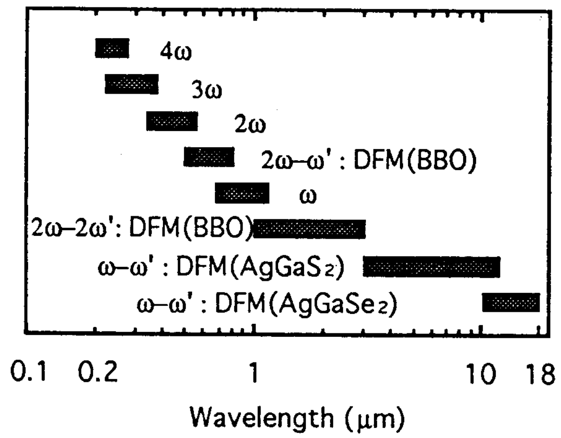

Fig. 2 Calculated tuning range of the fundamental and converted waves by DFM and harmonic generation of the Ti:Al_2O_3 laser system.

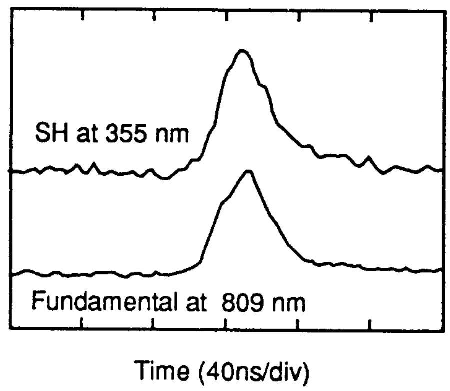

Fig. 4 Temporal pulse shapes of SH at 355 nm and fundamental at 809 nm.