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DEVELOPMENT OF SUPERCONTINUUM LIGHT PRODUCTION SYSTEM USING Er FIBER LASER FOR PULSE RADIOLYSIS*

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Abstract

Pulse radiolysis is one of the methods to elucidate radiation chemical reactions. In order to elucidate that, not only high temporal resolution, but also a light source with a broad spectrum band is required. A Xe flash lamp is mentioned as a light source having a broad spectrum band. However, in measurement using a Xe flash lamp, the time resolution is limited to the nanosecond order. In this research, we have developed supercontinuum light as a light source that enables picosecond time resolution and has a broader spectrum band. In this paper, we developed a light source using an Er doped fiber laser for pulse radiolysis measurement, and report the results and future prospects here.

INTRODUCTION

Pulse Radiolysis

Nowadays, there are many radiation chemical industrial products in present society. Thus, it is very important to elucidate the fundamental process of radiation chemical reactions. Pulse radiolysis technique is one of the most powerful methods to elucidate radiation chemical reactions. Typical scheme of the pulse radiolysis system is shown in Fig. 1. When some materials are irradiated by the ionising radiation, various kinds of reactive intermediates are produced. The reactive species, which are excited states, ionic species, radicals and their related species, will be produced in the irradiated materials. These species can be characterized and observed by the optical absorption with the certain time resolutions. In the practical way, the measurement is performed by observing the change of light intensity with certain wavelength in the analysis light, which is introduced to the sample cell at certain timings with the ionizing radiation.

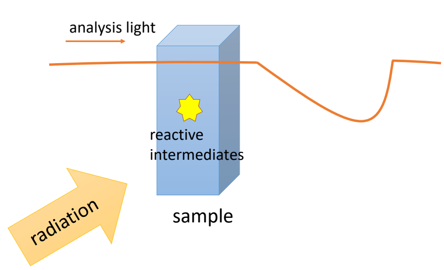

Figure 1: Scheme of the pulse radiolysis system.

A light source used for pulse radiolysis is required to have high intensity, stability, and a broad spectrum band. Xe flash lamps are widely used because they satisfy these requirements. However, the time resolution of the system using a Xe flash lamp is normally depended on the time resolution of the photo detectors, and it is generally limited to the nanosecond order.

Thus, it is necessary to use the stroboscopic method with an ultrafast laser to conduct experiments with better time resolution. The typical schematic drawing of the stroboscopic method is shown in Fig. 2. Pulsed radiation and pulsed analytical light are simultaneously incident to measure generated reactive species. At this time, transient absorption is time-profiled by repeating the measurement which changed the arrival time of the analysis light pulse to the irradiation. Therefore, the analysing light needs to be a supercontinuum light which has the features as short pulse, wide spectrum band and good M^2. In this study, we will report the newly developed supercontinuum light source with a broad band spectrum in the visible light region to replace the Xe flash lamp.

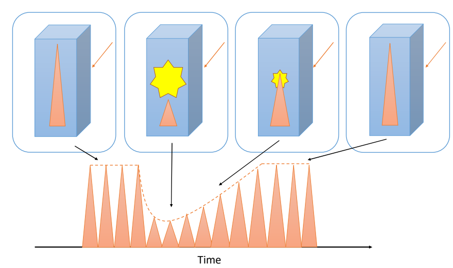

Figure 2: The typical schematic drawing of the stroboscopic method.

Supercontinuum Light

Supercontinuum light is continuous and broadband laser light It can be obtained by impinging ultrashort pulses on a nonlinear optical material such as PCF (Photonic Crystal Fiber) [1]. Ultrashort pulses is whitened by the nonlinear optical effects such as self-phase modulation, four-wave mixing and Raman scattering. It has not only the properties of a laser, such as high intensity, short pulse, high stability, and high directivity, but also has the properties of a broad band wavelength spectrum band, so it is very suitable as a light source for pulse radiolysis. In previous research, we have obtained supercontinuum light using Yb doped fiber. The results are shown in Fig. 3. It can be confirmed that the wavelength is broadened from about 1030 nm to about 750 nm. However, the visible light spectrum band on the shorter wavelength side was not stable and could not be obtained. Therefore, in order to obtain a light source covering the visible light region, we are now trying to generate supercontinuum light using an Er doped fiber laser. The purpose of this research is to develop a broadband light source, which covers the most important region for pulse radiolysis 300 – 800nm, by utilizing supercontinuum light

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originated from the second harmonic of Er douped fiber laser.

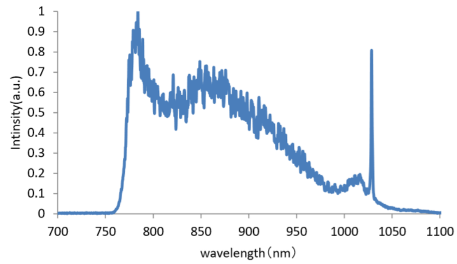

Figure 3: Spectrum band of supercontinuum light obtained from Yb doped fiber.

EXPERIMENTAL SETUP

The procedure of supercontinuum light generation is shown in Fig. 4. In this setup, the CPA method is used to enable the generation of high-intensity and short-pulse laser light. The stretching and compression of the pulse is performed by the grating. A double clad fiber is used for the main amplifier to obtain a high quality and high intensity laser. In addition, LBO crystal is used for wavelength conversion. Finally, PCF is used to broaden the bandwidth.

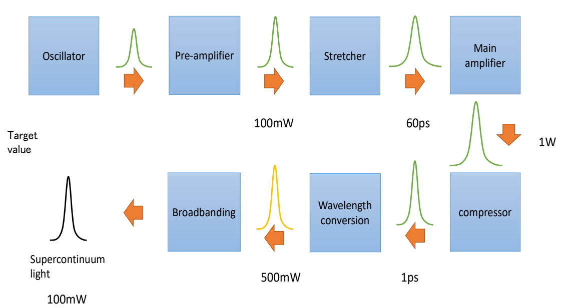

Figure 4: The procedure of supercontinuum light generation. The values in the figure show the target average power and pulse width at each stage.

RESULTS

The current setup is shown in Fig. 5. Constructions other than pulse compressors and band broadening system have been completed.

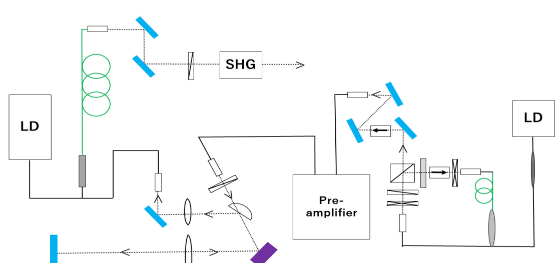

Figure 5: Current setup.

Oscillator

The performance of oscillator is shown in Table 1. The Er doped fiber used is Liekki Er 110-4/125 and the fiber length is 45cm.

Table 1: Performance of Oscillator

Frequency	52.825[MHz]
Average power	36.5[mW]
Pluse width	1.29[ps]
Energy	0.691[nJ]
Intencity	535[W]

Pre-amplifier

The performance of pre-amplifier is shown in Table 2. The same fiber as the oscillator used 85 cm. The output of excitation light is about 285 mW. It seems that there is no change compared to the value after the oscillator. This reason is the loss at the incidence of the collimator before the pre-amplifier, the signal before amplification is about 2 mW. Therefore, 12.5 dB is obtained as a gain. The saturated output obtained by the Er doped fiber amplifier can be calculated to be about 41 mW when the excitation light is 285 mW. Compared with this, the obtained value is considered to be valid although it does not reach the value to be achieved.

Table 2: Performance of Pre-amplifier

Excitation intensity	285[mW]
Output	35.9[mW]
Gain	12.5[dB]

Pulse Stretcher

The power after stretcher was 16mW. It has lost more than half of the output. It is difficult to evaluate the performance because the output after pulse stretching is low. Measurement of the pulse width after amplification and simulation showed that it was considered that expansion was not sufficient compared to the value to be achieved. Theoretically, further extension is possible by increasing the number of passes of the grating. However, considering the loss of output due to the increase in the number of passes, further expansion is difficult at the present time, because sufficient output is not obtained by the pre-amplifier.

Main Amplifier

The performance of main amplifier is shown in Table 3. The fiber used is CoreActive DCF-EY06 / 105/125, and the fiber length is 6 m. The output obtained here has the limit that can maintain the stability of the pulse, and it should be possible to expect more amplifiers. The cause may be that the output of the seed light is insufficient, and the pulse width is not sufficiently extended.

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Table 3: Performance of Main Amplifier

Excitation intensity	1.49[W]
Output	306[mW]
Pluse width	9.68[ps]
Gain	29.4[dB]
Energy	5.79[nJ]
Intencity	587[W]

Wavelength Conversion

The spectrum after wavelength conversion by LBO crystal is shown in Fig. 6. Measured values are summarized in Table 4. The presence of a peak around 775 nm, which is the second harmonic of 1550 nm, can be successfully confirmed. However, the drop in output after conversion is remarkable, about 2.4%. The cause is considered that the pulse width is not optimized with the crystal. Since the construction of the compressor is not completed at present, the width of the incident pulse is considered to be longer than the optimum.

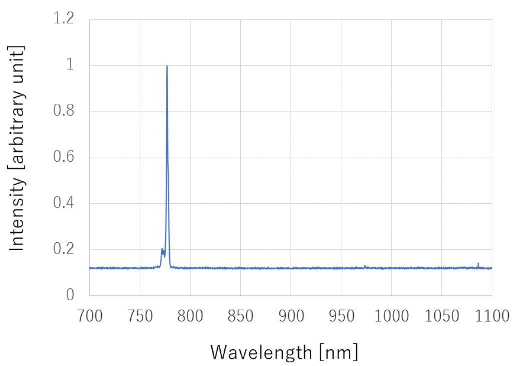

Figure 6: Spectrum of second harmonic.

Table 4: Performance of Wavelength Conversion

Output	6[mW]
Conversion efficiency	2.4[%]

IMPROVEMENT

As mentioned above, although this study could confirm the double wave for incidence to PCF, many problems remain and it is still under the progress of the production. There are two improvement plans. One is an increase in output [2]. A main reason of insufficient performance of pulse stretch and main amplifier is considered to be caused by the lack of incident power. We are considering adding another amplifier to the setup there. As a result, it is estimated that sufficient output and pulse width can be secured for the value. Also, making the stretcher a fiber type instead of a grating should improve stability and reduce a loss of power.

The other is the improvement of the conversion efficiency of the double wave generation by the crystal. Apart from the optimization of the pulse width, we consider the optimization of the crystal. It is thought that about 50% conversion efficiency can be achieved in the crystal called PPLN. In the future, if the conversion efficiency remains low, we will consider the use of SHG other than LBO crystals.

CONCLUSION

We aim to produce supercontinuum light using Er doped fiber laser. At present, the generation of second harmonics has been confirmed. Also, performance and stability are not sufficient. The current challenge is to improve the output and obtain broadband light. When supercontinuum light is obtained, pulse radiolysis experiments are actually conducted to evaluate the light source.

REFERENCES

[1] Jinendra K. *et al*., "Visible continuum generation in air-silica microstructure optical fibers with anomalous dispersion at 800nm", *IEEJ Transactions on Electronics, Information and Systems*, Vol.132 No.11 pp.1873-1879.

[2] Grzegorz Sobon *et al.*, "High-Power Fiber-Based Femtosecond CPA System at 1560 nm" IEEE Journal of Selected Topics in Quantum Electronics, Vol. 20, No. 5, September/October 2014.