Supercontinuum Generation for the Improvement of Pulse Radiolysis System

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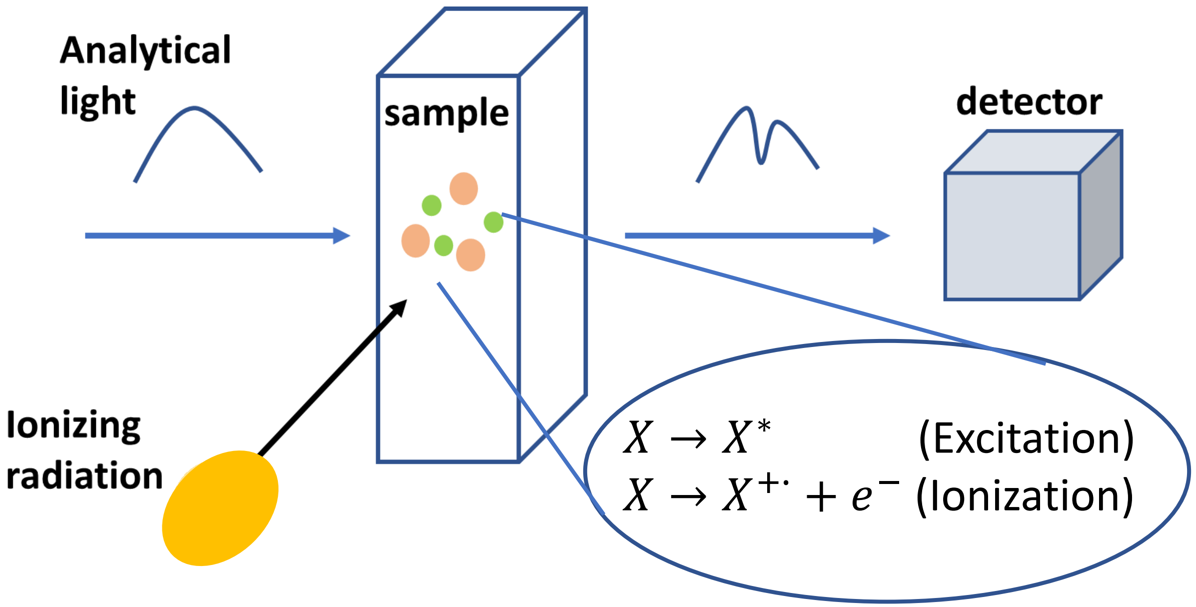
Abstract

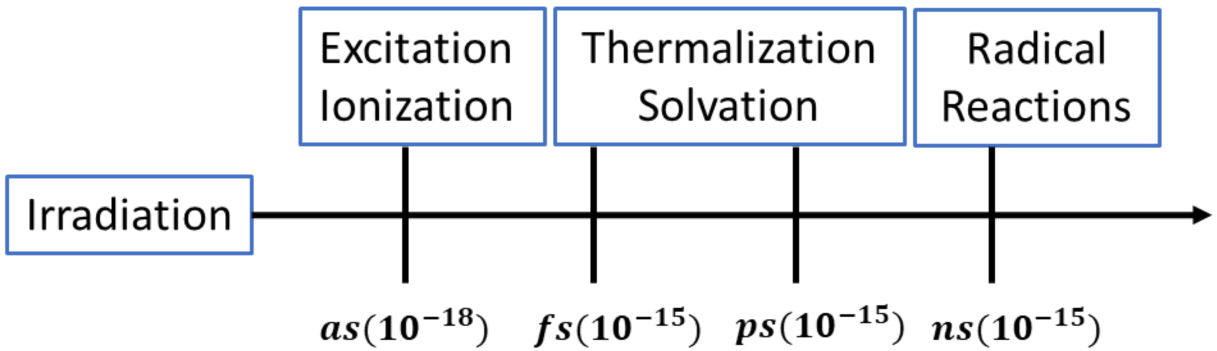
Pulse radiolysis is one of the absorption measurement methods for investigating the fundamental, ultrafast process of radiation chemical reactions. Analytical light is transmitted simultaneously with the timing of electron beam irradiation, and its absorption by reactive species is detected. Since the target reactions arise in pico second time scale or even shorter, analytical light is required to have such duration. Besides, so as not to be buried in noise of the radiation source, the optical power of the analytical light must be high enough. Furthermore, it is desirable that the analytical light covers visible region because important absorptions caused by irradiation products such as hydrated electron, hydroxyl radical, or so exist in the region. We considered that the supercontinuum light generated from an ultrashort pulse laser is suitable as an analytical light because it has all these characteristics. In this study, we generate the second harmonic (775 nm) of an erbium fiber laser (1550 nm) as a seed laser for supercontinuum generation. In this presentation, we report the current situation of our laser system and prospects.

Introduction

Pulse radiolysis

Transient absorption measurement methods for investigating the fundamental, ultrafast process of radiation chemical reactions





Reactive species decay in nano or pico seconds.

→<u>Analytical light pulse duration needs to be as short.</u>

Absorption must be detected without being buried in the noise from the accelerator.

→<u>Optical power of the analytical light must be high enough.</u>

Absorption wavelength varies depending on the reactive species.

Absorption of important species exist in visible region.

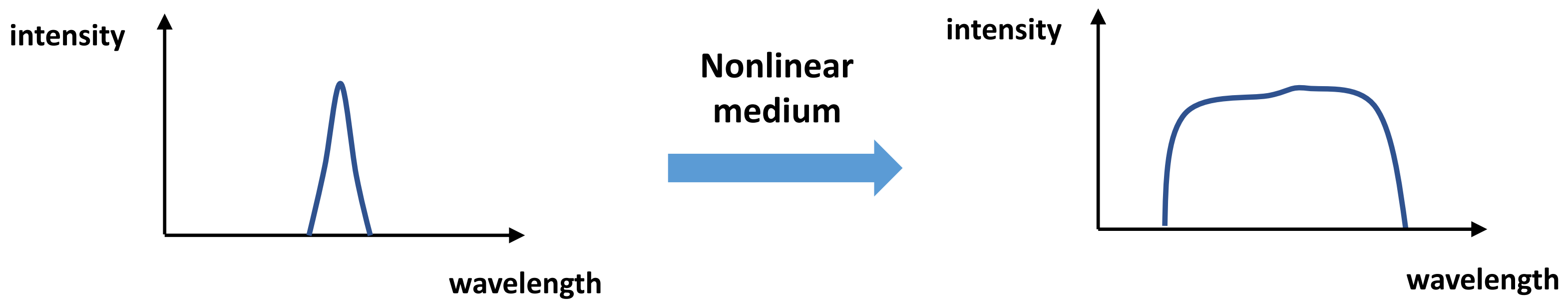
→<u>It is desirable for the analytical light to have a broad spectrum in the visible region.</u>

Supercontinuum Light is suitable for the analytical light.

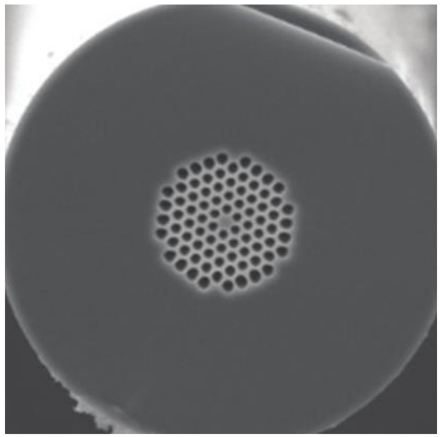
Introduction

Supercontinuum Light (SC Light)

Ultrashort pulsed light with a wide wavelength band broadened by nonlinear optical effects in the nonlinear medium



We use photonic crystal fiber (PCF) as the nonlinear medium



Sectional view of the PCF[1]

[1]PHOTONICS BRETAGNE, SUPPCF Combined Spec Sheet-032019 https://www.photonics-bretagne.com/wp-content/uploads/2019/09/SUPPCF-Combined-Spec-Sheet-032019.pdf

PCF：Fiber with small effective area and high nonlinear coefficient

Parameters of our PCF

Core diameter (μm)	1.71
Cladding diameter (μm)	135
Zero dispersion wavelength (nm)	772
Length (m)	3

Introduction

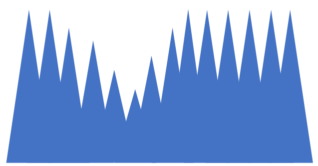
Improvement of pulse radiolysis system by SC light

①SC light can be applied for nano and pico second time resolution measurements

②Compactness of fiber based system

① Absorption measurement according to repetition time
(nano second time scale, per pulse)

Add a picosecond delay to the timing
According to the delay time
(Strobe Scopic Method)



② SC generation using the second harmonic of Er fiber laser

Er fiber laser (1550nm)

↓ nonlinear optical crystal
(PPLN crystal)

Second harmonic (775nm)

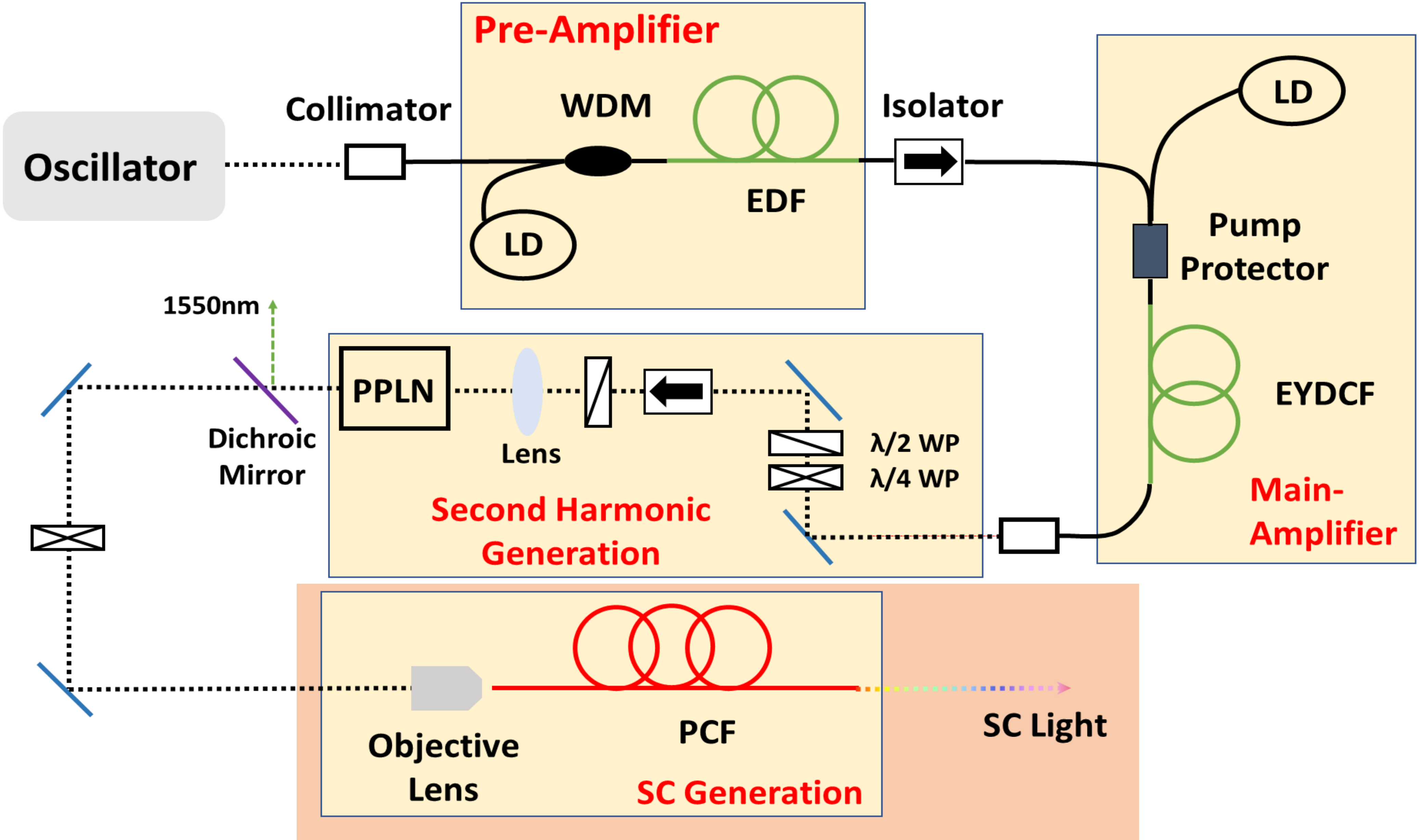
↓ PCF

SC light (broadband)

Laser System

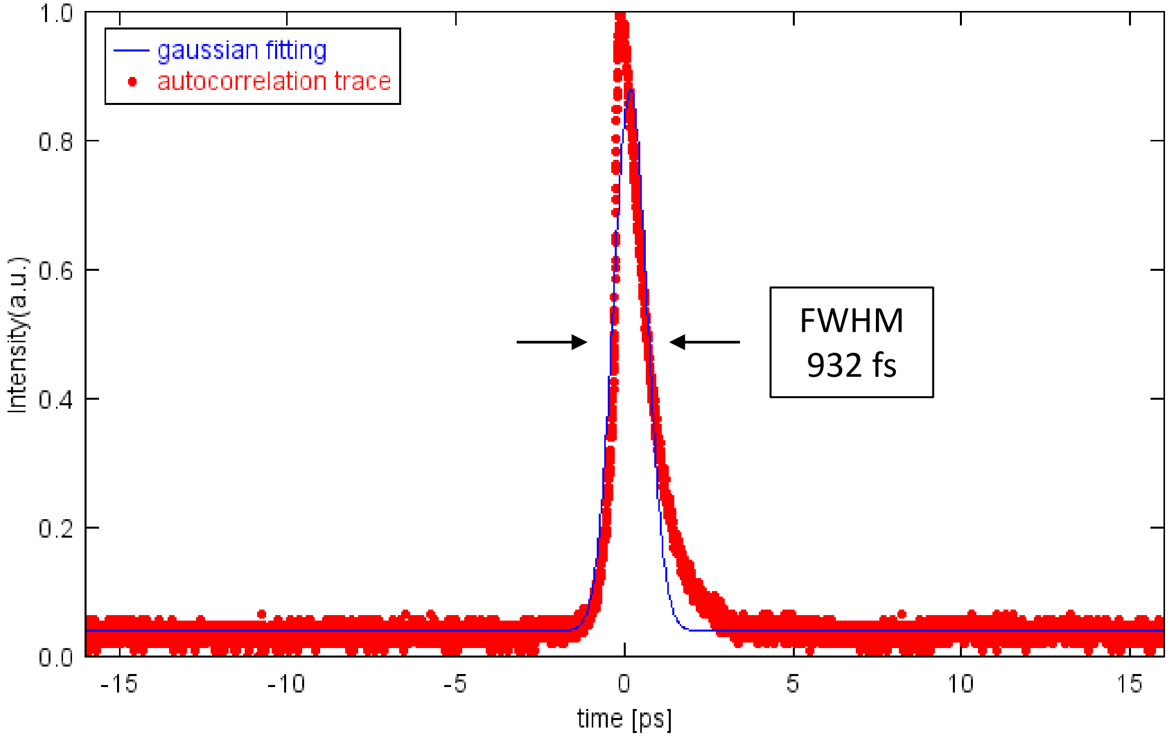
Overview of our laser system

Laser system is now under construction.

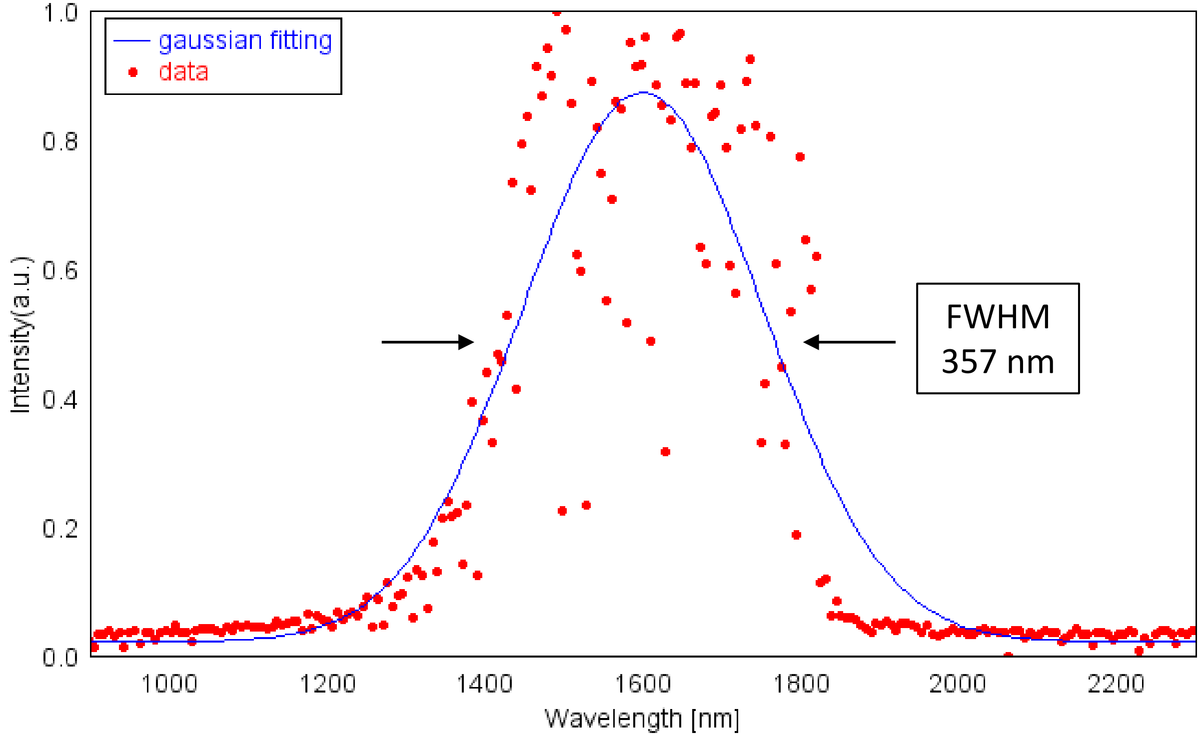


※We haven't obtained SC light because of low conversion efficiency to the second harmonic.

Laser System



autocorrelation trace after main amplifier



spectrum after main amplifier

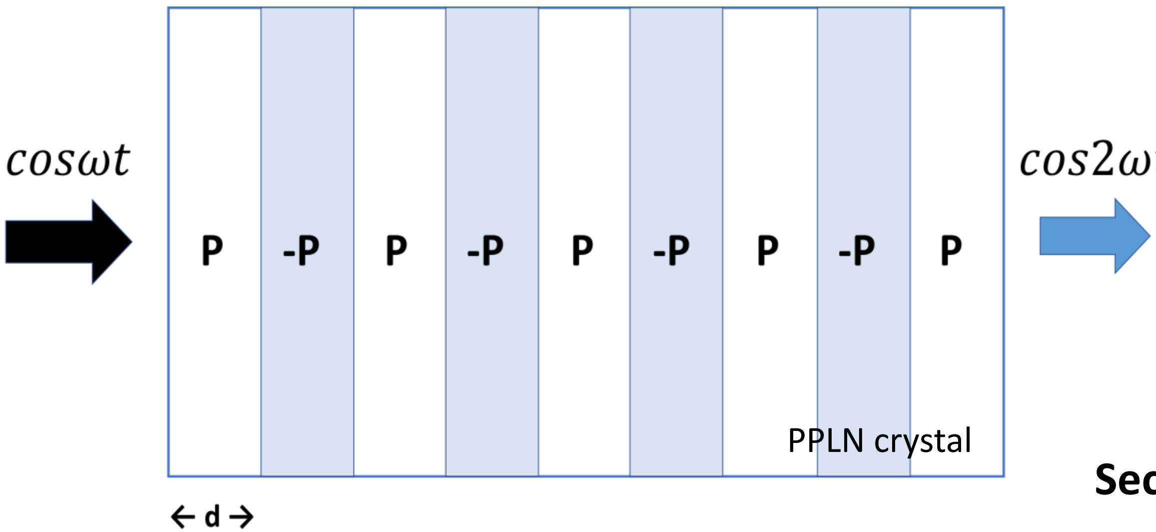
Parameters of laser after main amplifier

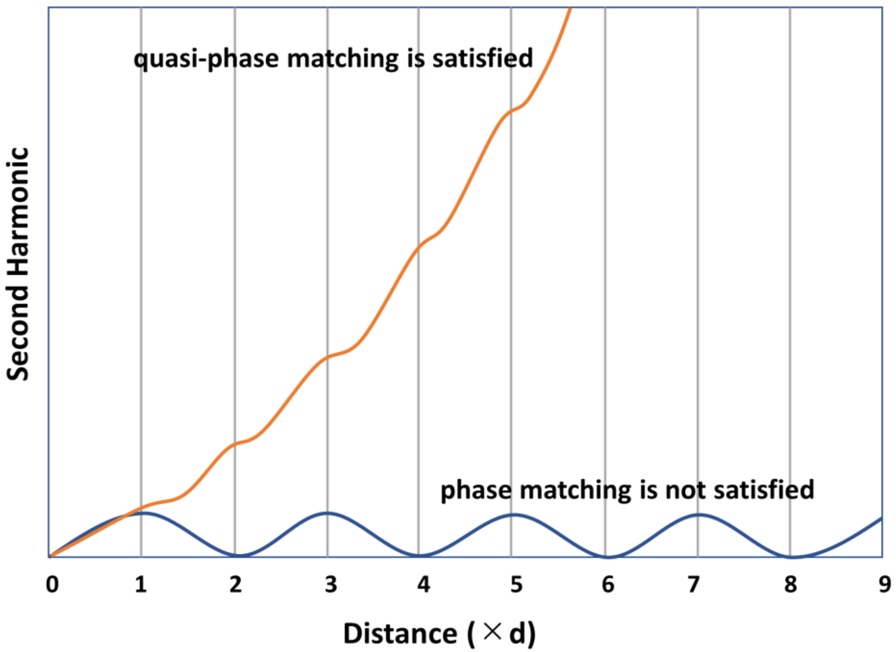
repetition frequency (MHz)	52.8
average power (mW)	625
pulse duration (fs)	932
peak power (kW)	12.7
spectrum width (nm)	357
central wavelength (nm)	1599

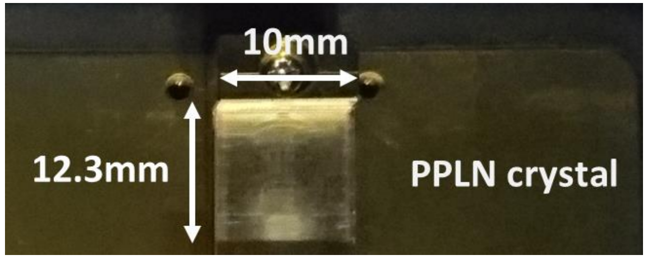
Laser System

Second Harmonic Generation

Wavelength conversion is achieved by periodically poled lithium niobate (PPLN).







Picture of PPLN crystal

Second harmonic generation by quasi-phase matching (QPM)

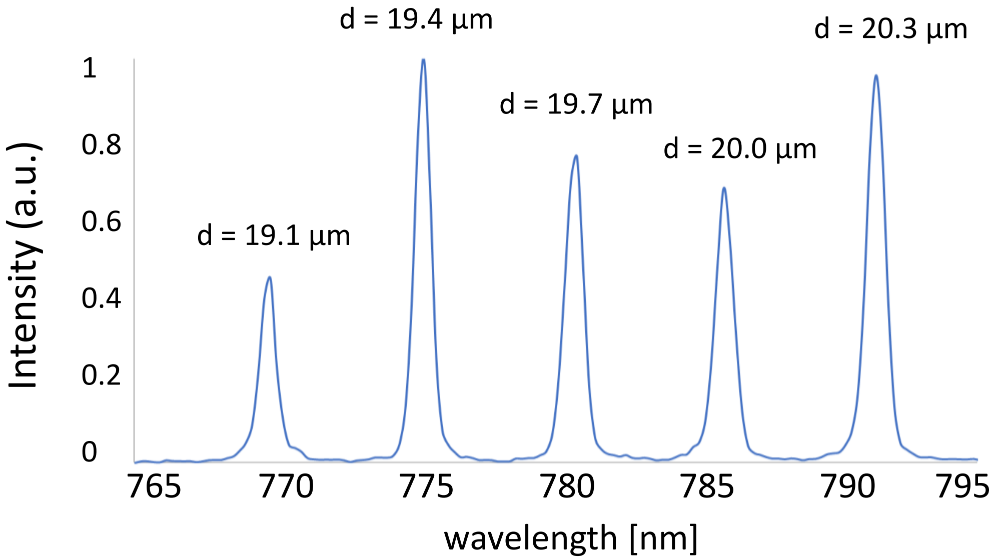
- The phase mismatching between the fundamental wave and the second harmonic is compensated by periodic polarization reversal.

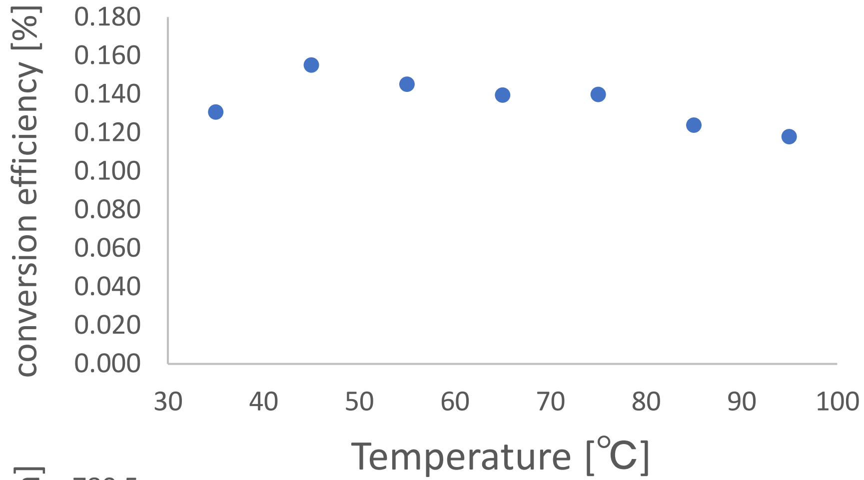
$$\text{QPM condition}: d = \frac{\lambda_{SH}}{2\{n_{sh}(T) - n_F(T)\}}$$

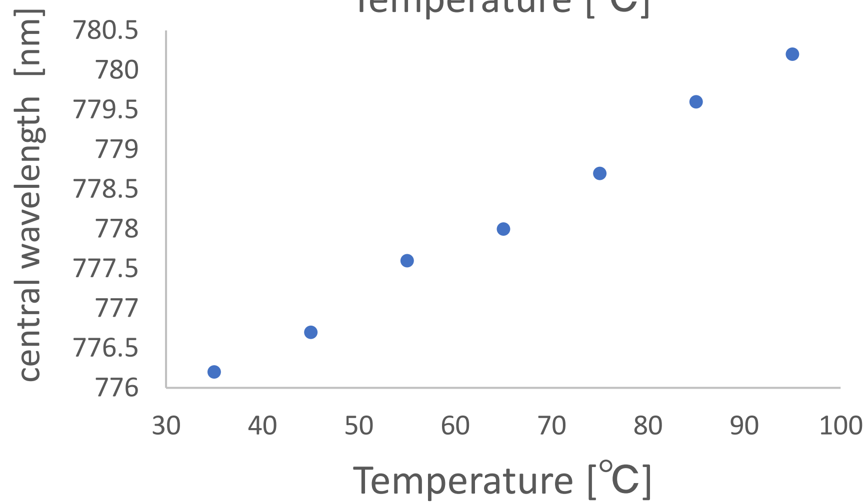
d: polarization reversal period , λ_{SH} : second harmonic wavelength
n_{SH}: refractive index of SH, n_F: fundamental wavelength

Laser System

Second Harmonic Generation







Second harmonic parameters (25℃, d = 19.4 μm)

maximum average power (mW)	3.19
maximum conversion efficiency(%)	0.51

- Central wavelength of second harmonic is up to *d*, and there are 10 different *d*s in our PPLN crystal.
- Very low conversion efficiency
- We can change PPLN crystal temperature, but conversion efficiency does not improve so much.
- We consider that low conversion efficiency is due to inadequate optical power of the seed laser.

➡ **We have to improve the peak power of the seed laser. (i.e. shorter pulse duration and higher average power)**

Summary

- Supercontinuum generation for the improvement of pulse radiolysis system
- We use the second harmonic of Er fiber laser as a seed for PCF
- We haven’t obtained SC light yet because of low conversion efficiency to the second harmonic

Prospects

- For shorter pulse, we will introduce grating pairs as dispersion compensation after main amplifier.
- After that we will generate second harmonic with sufficient peak power for SC generation.
- Then SC light will be generated and evaluated as the analytical light for pulse radiolysis.