92 - Research and Development of Tabletop Ion Accelerator

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Introduction

The effect of Radiation ··· Benefit & Harm

【Benefit】
Radiation therapy for cancer

Heavy ion radiotherapy

Less damage on normal tissue than X-ray radiation therapy.

Fig.1 Heavy Ion Accelerator Facility : HIMAC[1]

【Harm】
Radiation damage to human body

Work under high dose

Some people work under high dose in a nuclear power plants.

Fig.2 Fukushima Daiichi Nuclear Power Plants

Business in space

We are irradiated by cosmic ray.

Fig.3 Astronaut

【Subject】

There is not enough statistical data evaluating the influence of ion beam on DNA.

We have been developing a low-energy compact ion accelerator for a real-time detection system of DNA damage and repair induced by heavy ion beam.

Purpose

We have developing a tabletop ion accelerator system.

【Beam Parameters of Ion Beam】

Particle	Charge state	Energy	Size[m]
Carbon	6^+	1 MeV/u	a few meter

Application :
The real-time DNA lesion and repair monitoring system

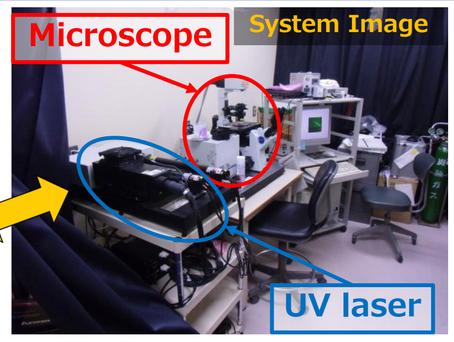

Fig.4 Laser irradiating systems (Tohoku University @ Yasui Lab)

Compact Ion Accelerator

【Acceleration by Superposed Electric Field】

Ions are accelerated **repeatedly** by pulsed electric field, which appears when ions arrive.

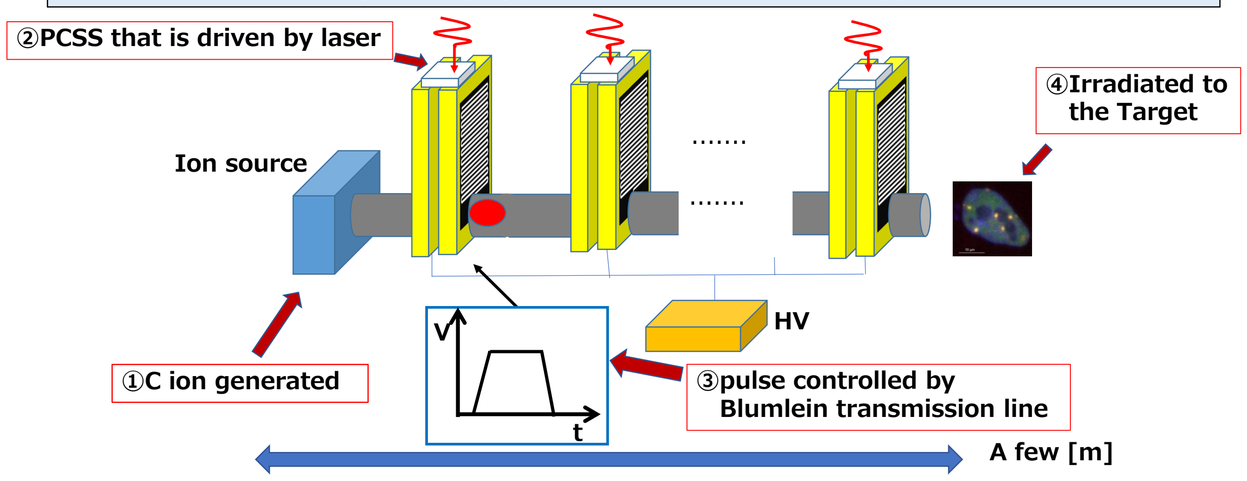

Fig.5 The schematic diagram of Tabletop Ion Accelerator

①Ion Source

【Laser Ion Source】
Laser ion source is based on plasma generation by high-power laser focused onto a target[2].

【Advantages】
- ✓High current
- ✓High charged state
- ✓High directionality
- ✓Low emittance

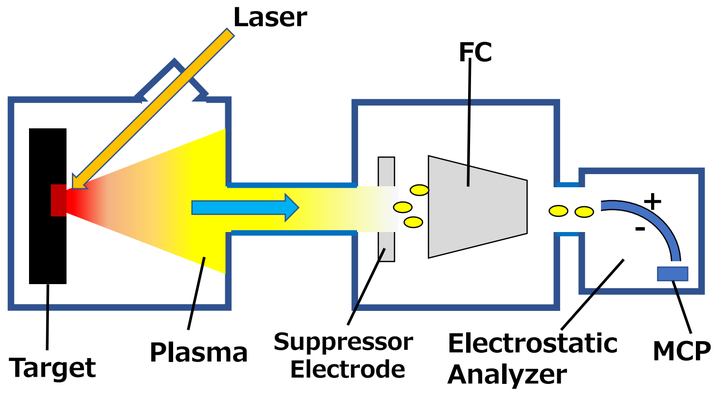

Fig.6 The schematic diagram of laser ion source

- The target is **carbon graphite.**
- The plasma current was measured by Faraday cup (FC).

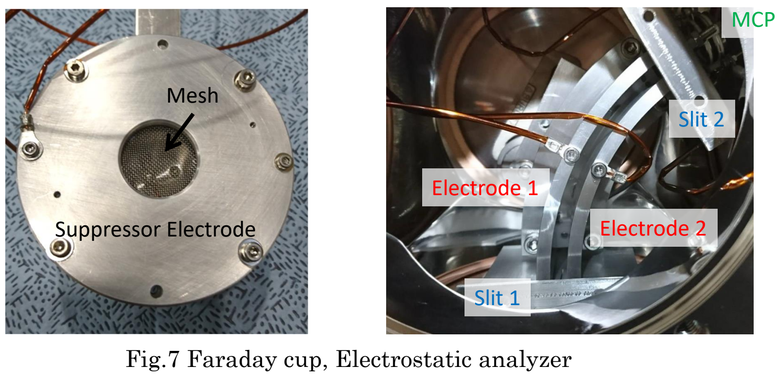

Fig.7 Faraday cup, Electrostatic analyzer

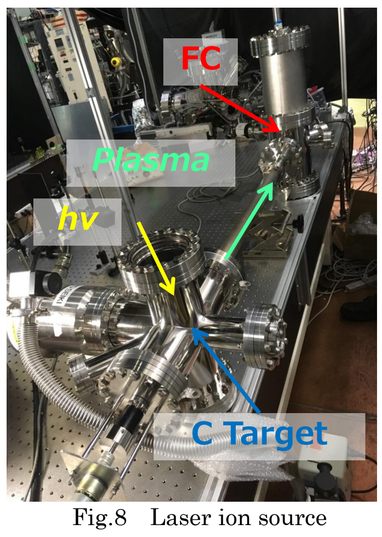

Fig.8 Laser ion source

Ion current Measurement

【Laser parameter】

Laser	Nd:YAG
Wavelength	1064 nm
Pulse width	20 ns
Pulse energy	250 mJ

The peak ion current = 10.3 mA

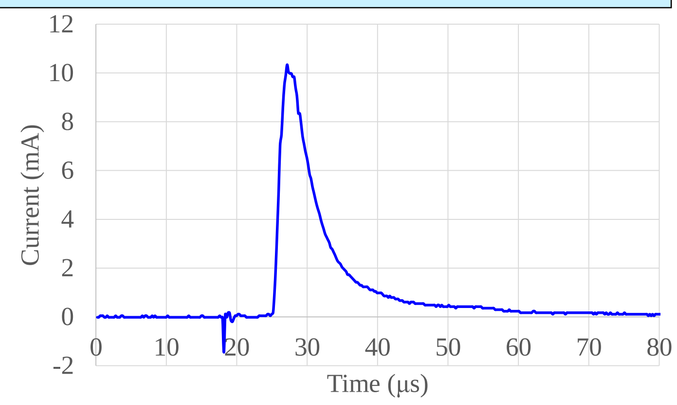

Fig.9 Voltage vs Time

②PCSS

【Photoconductive Semiconductor Switch】
PCSS is driven by light such as laser. In semiconductor, electron-hole pairs are generated by the photon energy and that work as carrier.

【Advantages】
- ✓Fast response (~10 ns [4])
- ✓Long lifetime (>10^6 shots [3])
- ✓Tolerance to high voltage (>10 kV [3])

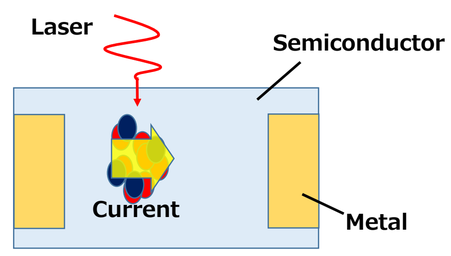

Fig10 The schematic diagram of PCSS

【Fabrication】
Three kinds of PCSS was fabricated at NIMS Nanofabrication Platform.

Gap : 6 mm, 8 mm, 12 mm

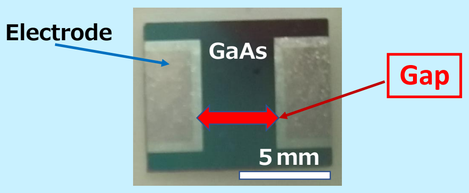

Fig.11 PCSS

【Target Spec of PCSS】
①On-resistance (Target value : < 10 Ω)
②Rise-time (Target value : < 10 ns)

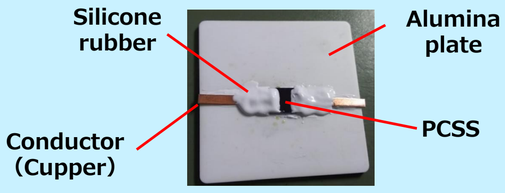

Fig.12 PCSS configuration

【Experiments】

On-resistance & Rise-time of PCSS was measured.

Attenuator	: 150W, 20dB
Trigger laser	: Nd:YAG laser
Laser power	: 1-40mJ @1064nm
Laser pulse width	: 20ns (FWHM)

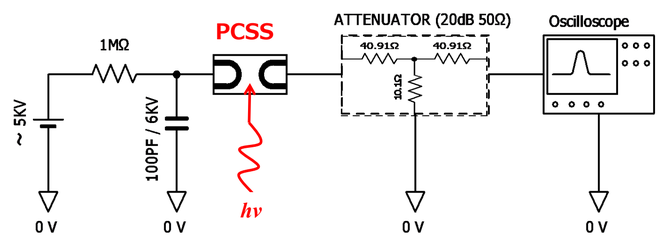

Fig.13 The schematic diagram of the circuit

【On-resistance】

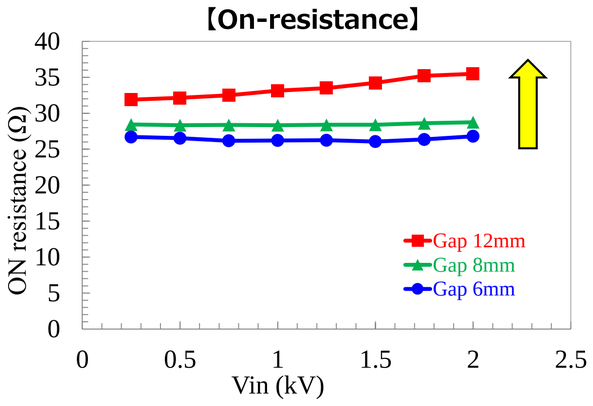

Fig.14 Vin vs On-resistance

The shorter Gap is, the less On-resistance becomes.
➡ Resistance depends on the length.

【Rise-time】

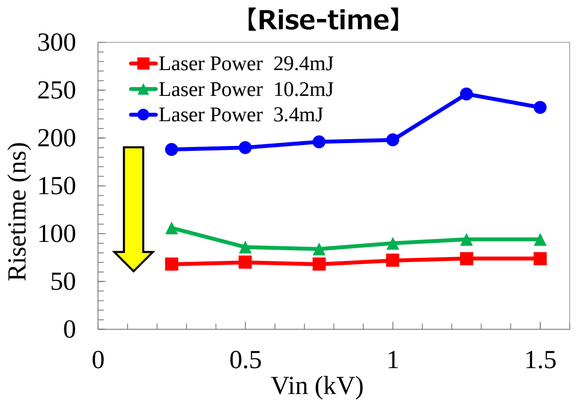

Fig.15 Vin vs Rise-time

The bigger the laser power is, the shorter the rise-time becomes.
➡ The amount of electron-hole pair production becomes bigger.

【The improvement】

The thickness of the electrode and the temeperarure of anneal may change the resistance.

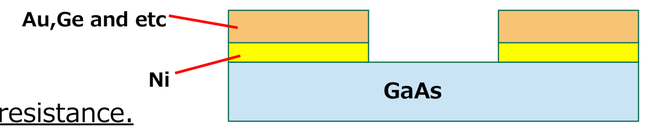

Fig.16 The new design of PCSS

Conclusion and Future plan

- ✓ Compact ion accelerator has been developed for radiation biological experiments.
- ✓ We built the C ion source and measured the ion current.
- ✓ The charged sate distribution will be analyzed.
- ✓ We fabricated PCSS and carried out the characteristic evaluation.
  - ・The shorter Gap is, the less On-resistance becomes.
  - ・The bigger the laser power is, the shorter the rise-time becomes.
- ✓Blumlein transmission line has been under design for beam acceleration.

【References】

[1] NIRS http://www.nirs.go.jp/index.shtml.
[2] Boris Sharkov and Richard Scrivens, “Laser Ion Sources”, IEEE Transactions On Plasma Scince, Vol. 33, No. 6,(2005).
[3] Chongbiao Luan, et al., “Study on the high-power semi-insulating GaAs PCSS with quantum well structure”, AIP Advances **6**, 055216-1-055216-5, (2016).
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【Acknowledgement】
This study has been supported by JSPS KAKENHI (16H07443, 17H06126) and MEXT Nanotechnology Platform (NIMS Nanofabrication Platform).