The Experimental Results of Fast Switching System for Millimeter Wave Transmission using Photo-excited Semiconductor

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***Abstract*— Photo-excited semiconductor switching system for fast control of millimeter wave is developed and tested with an oversized corrugated horn ($D/\lambda > 10$) and quasi-optical mirror setup. Semi-insulating GaAs (100) having direct band-gap shows fast switch ON-OFF (< 100 ns) whereas semi-insulating Si (100) having indirect band-gap shows fast switch ON (< 100 ns) and slow switch OFF (< 1 ms) for the millimeter-wave regime.**

I. INTRODUCTION

Neo-classical tearing mode (NTM) instability control is one of the challenging missions toward steady-state drive in fusion plasma [1]. Fast modulating of millimeter waves from high-power gyrotron is proven to be an efficient way to control the instability. Fast mechanical switching is limited to seconds and is extremely difficult due to technical limitation. We suggest new concept of fast switching system using glow discharge plasma with a few μ-seconds pulse modulation. In order to do proof-of-concept study, we design quasi-optical switching system using photo-excited semi-conductor instead of glow discharge plasma to predict the millimeter wave transmission as a function of plasma density. When un-doped semiconductor containing low density of carriers is excited by optical pumping, density of carriers is changed by carrier generation and recombination [2]. From this, we can define plasma frequency having relationship with propagated electromagnetic waves. We choose short pulse laser (532 nm wavelength, duration: 15~18 ns) as an optical pump source to change plasma frequency of semi-conductor. The Gaussian beam coming from oversized corrugated horn antenna ($D/\lambda > 10$) is strongly focused (~ 2.5 λ) on semiconductor surface for matching laser spot size. (D : radius of corrugated horn antenna, λ: wavelength of millimeter wave)

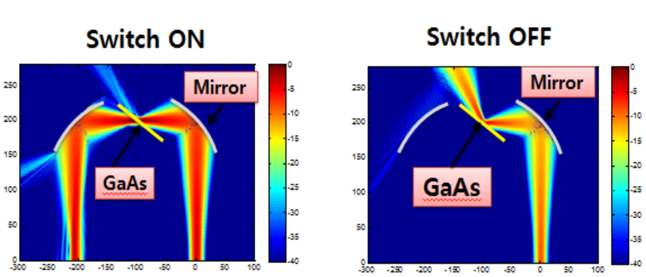

Fig. 1. Quasi-optical switching system simulation in COMSOL multi-physics

II. EXPERIMENTAL SETUP

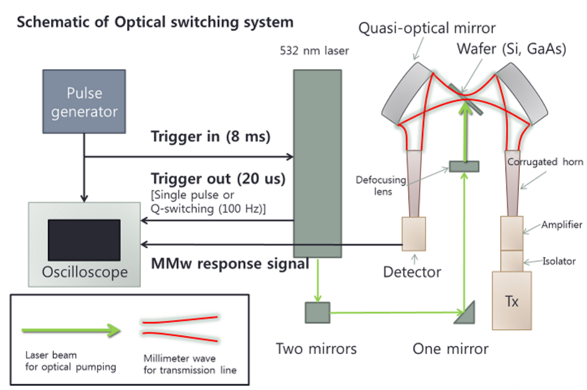

Fig. 2. Schematic of quasi-optical switching system using semiconductor

In millimeter wave region, millimeter source coming from Vector network analyzer pass through isolator, amplifier and corrugated horn antenna for make high power Gaussian beam. Wafer angle is set to 60° for reduce the noise when switch is turn off. Figure 1 is shown Gaussian beam path according to switch state. Laser source is defocused on the lens. Defocused laser spot size is larger than millimeter wave beam diameter at wafer. Schottky diode detector has fast and sensitive response around nano-second range to observe precise characteristic of semiconductor. In oscilloscope, sampling rate is 10Gb/s and signal is averaged around 100 times for reduce error. 50 ohm load is used for impedance matching.

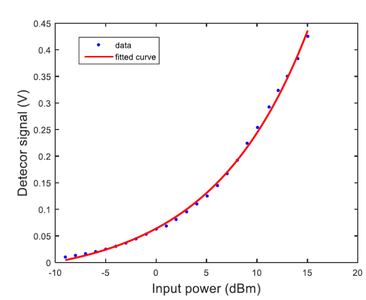

Fig. 3. Detector power calibration fitting results by power meter

Signal from schottky diode detector convert to calibrated power though power meter. Figure 3 is shown that calibration power is fitted by exponential growth. Through these fitting results, we can get transmittance of millimeter wave at time domain.

III. RESULTS

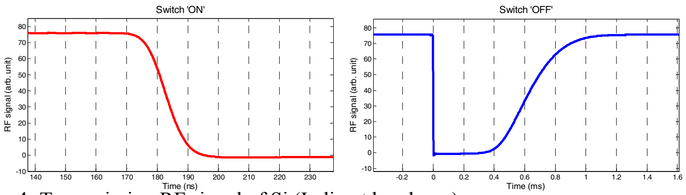

Fig. 4. Transmission RF signal of Si (Indirect band-gap)
(a) Fall time of RF signal (Switch ON)
(b) Rise time of RF signal (Switch OFF)

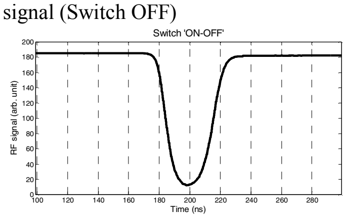

Fig. 5. Transmission RF signal of GaAs (Direct band-gap)

In Fig. 4 and Fig. 5, we present time-domain RF signal from Schottky diode detector passed through photo-excited semiconductor and quasi-optical mirror system. For the Si wafer case as shown in Fig.2 the fall time (Switch ON time < 100ns) is faster than the rise time (Switch OFF time < 1ms) since SRH recombination and auger recombination are dominated in indirect band-gap having high intrinsic carriers. On the other hand, for the GaAs wafer case in Fig. 3, we observed that the fall time is similar to the rise time (< 100ns) because of radiative recombination is dominated in direct band-gap [3].

IV. SUMMARY

Photo-excited semiconductor switching system is developed in millimeter wave transmission system. We observed nano-seconds switching time for the case of GaAs sample detected by RF-detector signal. Based on these results, we will estimate specification of semiconductor according to minority carrier life time and recombination effect. So we will compare advantage of transmittance measurement technic to reflected microwave measurement technic (u-PCD).[4]

We will apply this concept to sub-terahertz transmission system for development of ECH transmission line in fusion tokamak.

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