Demonstration of an optical interface for SFQ logic circuits

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INTRODUCTION

Single-flux-quantum (SFQ) logic circuits are expected to be operative at a clock rate above 100GHz with very low power consumption. A considerable amount of research has been performed on this topic, and noteworthy achievements, e.g. 120 GHz shift register [1] and microprocessor consists of over 10,000 junctions [2], have been reported recently. With the progress of the performance of SFQ circuits, development of technologies for the implementation of the circuits to various practical systems is becoming important field of study. Especially, development of an ultrafast optical interface for SFQ circuits is urgent and critical subject for SFQ circuits to apply high performance system because optical signals have various advantages to electrical signals in a sub-terahertz (THz) frequency region where SFQ circuits should be used. In such a high frequency region, large signal loss and impedance mismatch are inevitable using conventional copper transmission lines for electrical signals. Moreover, a copper wire has large thermal conductivity and need much cooling power to stably operate SFQ circuits.

On the other hand, various technologies with optical signals have been developed for a large capacity signal transmission for optical communication, e.g. time division multiplexing and wave division multiplexing. Furthermore, an optical fiber cable is suitable for connecting superconducting devices with the peripheral devices at the room temperature because it has very low thermal conductivity. Therefore, development of an ultrafast optical interface that converts optical signals to electrical signals make SFQ circuits very attractive as an emerging information-processing technology that could follow conventional devices based on CMOS technologies. Nevertheless, there have been only a few research attempts in this field up to now except for some fundamental researches [3, 4].

Up to now, we have reported fundamental researches on optical interfaces, for example, photoresponses of flux flow transistor, high-frequency signal injection to the Josephson junction using the photomixing technique, and so on. Furthermore, we also reported our work on an optical input interface using YBa2Cu3Ox (YBCO) thin films.

In this report, we introduce our approaches to realize the ultrafast optical input interface for SFQ circuits [5].

EXPERIMENTAL SETUP

SFQ circuits used in this study were consist of an optical-to-electrical converter with a pin-photodiode, a Josephson transmission line (JTL) with ramp-edge Josephson junctions made from YBCO thin films and a detector of SFQ signals with a DC SQUID sensor. The equivalent circuit and the scanning electron microscope image of the device used in this study are shown in Fig. 1 (a) and (b), respectively. The femtosecond optical pulses are illuminated to the pin-photodiode and converted to current pulses. The current pulses are introduced to JTL and converted to SFQ pulses. The generated SFQ pulses by the input current pulses are transmitted on JTL and stored at the final loop in the JTL, and are detected by the SQUID sensor fabricated close to the final loop. The device structure observed by a scanning electron microscope was shown in Fig. 1 (b).

A schematic illustration of the optical measurement system to evaluate the interface is shown in Fig. 2. The devices were mounted on the cold finger in the GM type cryostat in which the temperature was controlled with a resistive heater from 10 K to room temperature. An Er doped fiber laser with a center wavelength of 780 nm, a

Fig. 1 (a) The equivalent circuit of an optical interface (b) the scanning electron microscope image used in this study.
pulse width of 100 fs and a repetition rate of 50 MHz was used as the source of input optical signals. The repetition rate of input laser pulses was reduced by using an acousto-optic (AO) modulator that diffracts incident laser pulses only when bias voltage was applied. A pulse generator was used as an external voltage supply for the AO modulator to control the repetition rate. We changed repetition rates from 1 kHz to 100 kHz in this study. The bias current for JTL was supplied by a battery-powered DC current source and the output voltage of the SQUID detector was observed with a digital oscilloscope after the 1000 times amplification by the differential amplifier with 1 MHz bandwidth.

RESULTS AND DISCUSSION

The optical signals with the power of 3mW and the repetition rate of 100 kHz were illuminated to the pin-photodiode. In this case, generated current pulses in the pin-photodiode had pulse height of 6mA. Figure 3 shows the output signal from the SQUID detector and the trigger signal that is introduced into the AO modulator to control the repetition rate of input optical signals. The temperature of the interface circuit was 14 K. An output pulsed signal synchronized in the trigger signal for the AO modulator was observed. However, the output signal from the SQUID detector should be a step function if SFQ pulses were stored in the final loop in JTL as designed. Therefore, the results observed in this study indicate that the SQUID responds generated SFQ pulses passing through the JTL, however, it could not keep output voltage level because SFQ could not be stored in the final loop in JTL.

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REFERENCES