Nonlinear Response and Ultrafast Dynamics from Superconducting Thin Flims and Metamaterials

C. H. Zhang[1], B. B. Jin[1], J. Chen[1], M. Tonouchi[2] and P. H. Wu[1]
[1]Research Institute of Superconductor Electronics, Nanjing University, Nanjing, 210093 China
[2]Institute of Laser Engineering, Osaka University, Osaka, 5650871 Japan

***Abstract*— Recently, metamaterial in the terahertz (THz) region has become an attractive field as a novel approach to control and manipulate the electromagnetic waves. In this papaer, we report our recent development of nonlinear response and ultrafast dynamics from superconducting metamaterials at THz region measured by intense THz pump THz probe system. Both low temperature and high temperature superconducting thin films were studied for comparison.**

I. INTRODUCTION

DURING the recent years, intense terahertz (THz) time domain spectroscopy (TDS) has developed as a powerful tool to induce nonlinear response for kinds of materials in physics, chemical, and so on. Recently the intense THz TDS technology has led to more significant improvements, and has extend the linear studies to nonlinear region. Among them, the nonlinear metamaterial is especial attractive because of lack of natural THz devices, modulations, switches and so on. In this paper, we will show the ultrafast nonlinear response of our developed THz metamaterial.

II. RESULTS

In order to get the nonlinear transmission measurements, intense single-cycle terahertz radiation was generated by optical rectification in a $LiNbO_3$ crystal using tilted-pulse-front excitation[1-2]. The experimental setup consists of a 100-fs Ti: Sapphire regenerative amplifier (Spitfire, Spectra-Physics) operating at 800 nm with a repetition of 1 kHz, and the conventional electro-optical sampling technique is used to detect terahertz field (shown in Fig. 1). The incident terahertz beam was tightly focused onto the cryogenically cooled samples over a temperature range from 4.2 to 300 K. Meanwhile, the THz pump THz probe is also utilized to observe the dynamics of the nonlinear THz metamaterial.

To achieve THz metamaterial samples, superconducting NbN thin film was firstly deposited on 1-mm-thick MgO substrate (10×10 mm) using RF magnetron sputtering, then the standard photolithograph and reactive ion etching (RIE) method were taken to pattern the SRR structures

Here, superconducting YBCO and NbN thin film was firstly measured to observe the nonlinear response and ultrafast dynamics at THz region. Then we also demonstrated the nonlinear response of the superconducting metamaterial in the terahertz regime. The nonlinear response of the metamaterial lies in the suppression of the superconductivity of superconducting thin film induced by the intense terahertz wave. As the varying of the incident intense terahertz field alters the intrinsic conductivity in the superconducting thin film, a giant amplitude modulation is observed due to the strong nonlinearities. Increasing or decreasing the incident terahertz field strength, one can creates a sharper off or on transmission of the chosen superconducting metamaterial at the resonance frequency. The ultrafast dynamics was also observed by THz pump THz probe process, the decay time ranges from several hundreds of picoseconds to more than 1 ns for NbN samples and tens of picoseconds for YBCO samples, depending on the temperature and THz field intensity.

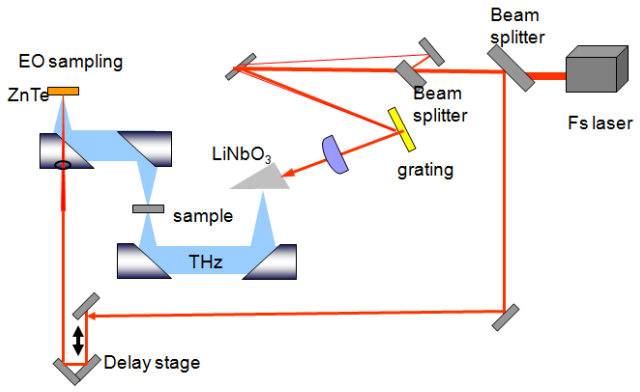

Fig. 1. Diagram of intense THz-pump THz-probe (single-cycle) time domain spectroscopy system

III. SUMMARY

In this paper, we studied the nonlinear response and ultrafast dynamics from low temperature and high temperature superconducting thin films and superconducting metamaterials.

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