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## Demonstration of a power handling of 0.5 kW at 0.4 GHz in a stripline of YBCO on a 3" LaAlO<sub>3</sub> wafer

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**ABSTRACT:** Thin YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7</sub> films were prepared by laser ablation deposition on 2" and 3" wafers of (100) LaAlO<sub>3</sub> and patterned into striplines with gold contacts for testing of microwave transmission versus power at 77K. For straight striplines along the diameter of the wafers, with 0.5μm x 5.5mm cross section we found that the power handling at 0.4GHz was 500-1000W for the striplines on the 2" wafers, and about 500W on the 3" wafers. Above these powers the striplines failed catastrophically, mainly near the normal gold contacts.

### 1. INTRODUCTION

This study is part of a project to build a multiplexer for power transmission of microwaves simultaneously in 4 channels, and to couple this power into a single antenna with minimum losses. The power requirements are that each channel should withstand up to 40W at 0.2-0.4GHz. To obtain this goal, we planned to use 4 phase shifters made of thin YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7</sub> (YBCO) films patterned into striplines and assembled in a special geometry which will be described later on. Each one of these shifters must be able to change the phase by up to 180° and 4 such shifters are needed. As a first step, large area films of high quality of the high temperature superconductor YBCO were prepared and patterned into straight striplines for testing the feasibility and power handling of the device. The films were prepared and patterned in the Technion, and the power handling experiments were carried out in Elisra.

### 2. EXPERIMENTAL

In order to prepare the large area films, we used a modified laser ablation deposition system as shown in Fig. 1. The main changes compared to a standard laser deposition systems are: i. The plume is not perpendicular to the wafer but at 45° to it, ii. This allows for a simple scanning of the heater in a horizontal plane which in turn enables, in principle, any size of coated area, iii. We added a commercial bottom heater to relax a bit the heating required from the top heater, which allowed us to use standard heating wires made of Kanthal. In addition, the top heater was made of ceramics, and its shape made it spread the heat quite evenly on the fragile LaAlO<sub>3</sub> (LAO) wafer to avoid breakage.

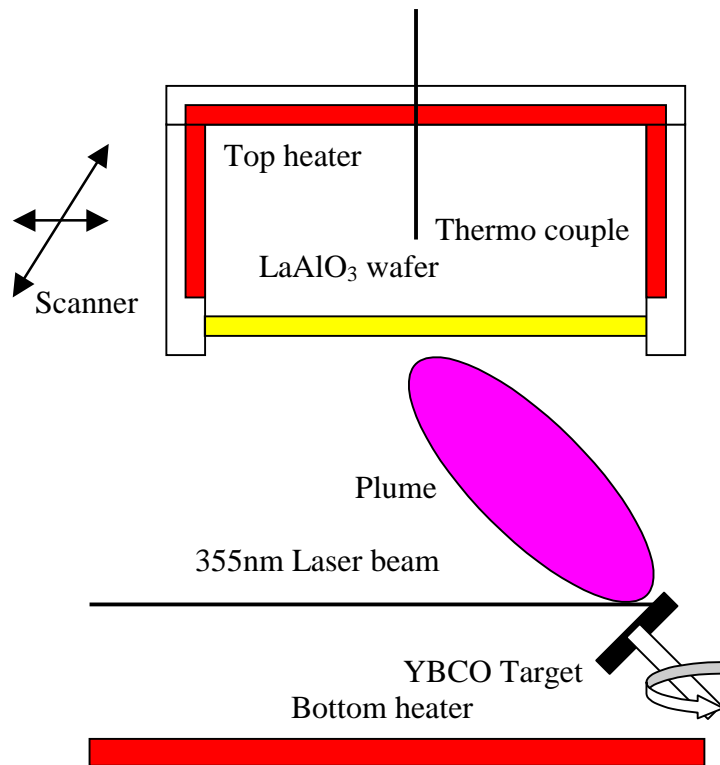


Fig. 1  
The laser deposition system

The deposition conditions were: 980 °C in the top heater and 1kW in the bottom heater, 0.1 Torr oxygen flow, 1-2J/cm<sup>2</sup> laser fluence on the target, 10Hz laser repetition rate, total of 20,000 laser pulses that produced about 500nm film thickness, and annealing in 20Torr of oxygen pressure. The  $T_c(0)$  of the resulting films are in the range of 88-90 K all over the wafer as can be seen in Fig. 2. Fig. 2 was obtained by a direct 4-probe transport measurement of 5 locations along the diameter of the wafers, parallel to the original direction of the plume. Since we used 4x5 spring loaded gold tipped contacts, the films were unharmed and used later on for the power testing. For this, the films were patterned by deep UV photolithography and wet acid etching into straight transmission lines as seen in Fig. 3 (a). Gold contacts were evaporated via shadow masks on the two edges of the stripline and the whole wafer was then reannealed in oxygen at 800°C. The patterned wafers were mounted in a simple testing chamber, and the contacts were connected to the input and output SMA connectors with several gold wires. We used wire bonding to the gold contacts on the stripline and electric welding to the SMA connectors. For the microwave power handling tests, the input SMA was connected to the microwave source and the output SMA to a 50Ω load. The test chamber was evacuated and filled with helium gas for good thermal exchange, and immersed slowly into a dewar filled with liquid nitrogen. The testing temperature was thus 77K, except for the normal gold contacts which were heated by the microwave power to a slightly higher temperature.

### 3. RESULTS

In the microwave transmission tests, the power through the stripline at 0.4GHz was increased slowly with dwells of a few minutes after each additional 50W. The transmitted and reflected power were monitored, until a catastrophic failure occurred.

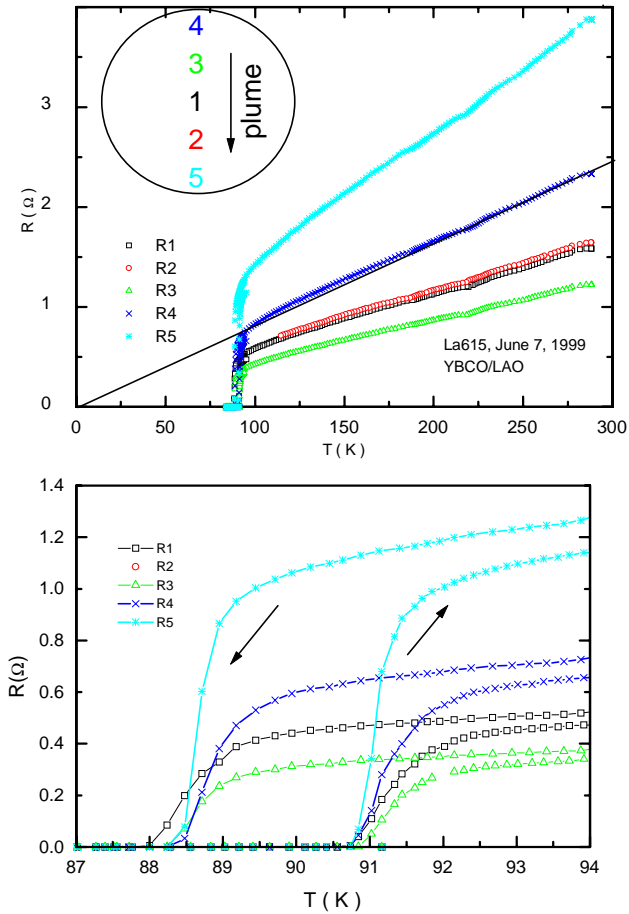


Fig. 2 Resistance versus temperature of 5 areas of the film along the diameter parallel to the plume.

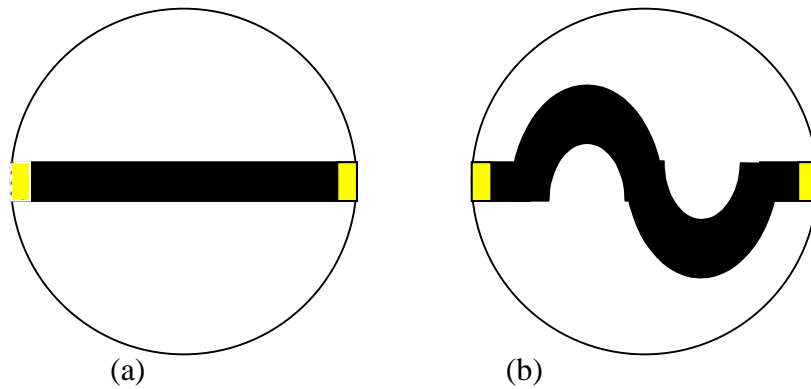


Fig. 3 The stripline for the power testing (a), and a typical stripline of the phase shifter (b).

We found that the power handling capability of the striplines on the 2" wafers ranged between 500 and 1000W and that of the striplines on the 3" wafers was about 500W. In all, we tested 12 striplines on the 2" wafers and 5 on the 3" wafers. The failure was generally caused by a damaged area in the stripline near the gold contacts, with burning marks and sometimes breakage or cracking of the wafer. We suspect that heating of the normal contacts is the cause of failure and this problem will have to be dealt with in the future. For now, the power handling results are satisfactory for the present project and we are in the stage of building the actual shifter made of YBCO. A schematic diagram of this device is shown in Fig. 4. It contains 4 wafers of 3" diameter two striplines in the form shown in Fig. 3 (b), and two ground planes.

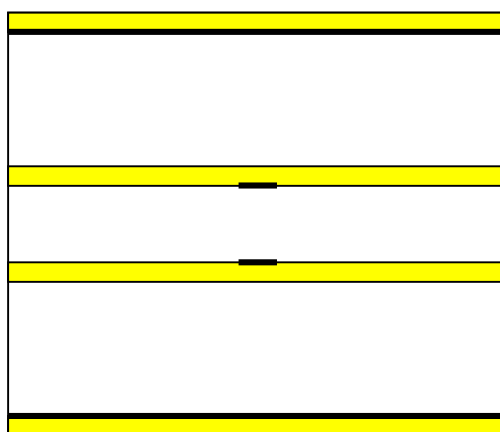


Fig. 4 A schematic cross section of the YBCO based phase shifter on the 3" wafers

So far we built a conventional such shifter with copper striplines and tested it under low power at room temperature. We measured a transmission loss of 0.6dB in the 0.2-0.4GHz range, while the calculated loss was 0.4dB. The calculated loss for the superconducting device is 0.2dB and it remains to be seen what the actual loss at high power will be. Finally, we should note that for 4 such shifters which are necessary for the whole multiplexer, we shall have to use 16 wafers, 8 with patterning and contacts like in Fig. 3 (b), and 8 unpatterned for the ground planes.