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Focusing THz radiation in $\mu$m-scale waveguides


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Abstract—THz coplanar waveguides were fabricated on quartz wafers with integrated epitaxially transferred low temperature grown gallium arsenide photoconductive switches. THz radiation was excited on-chip and transmitted through a tapering of the coplanar waveguide structure where it was focused down to $\sim 1.66\mu m$. Theoretical modelling of the device confirms high E-field confinement and concentration.

I. INTRODUCTION AND BACKGROUND

PLASMONIC devices are among the most promising for the control and focusing of THz radiation. The THz electric field couples to charge density oscillations in a metal allowing the effective transmission of THz radiation on metal waveguides on subwavelength length scales [4]. Possible applications include near-field imaging [1] and spectroscopy [5], while subwavelength control of THz radiation is a necessary step along the road to many potential integrated THz systems.

In this paper, tapered coplanar waveguides (CPWs), are both modelled and fabricated. THz pulse propagation through a CPW with total width of $\sim 1.66\mu m$ is demonstrated experimentally.

II. MODELLING

HFSS simulations were conducted for a tapered CPW. The starting width from ground plane to ground plane in the CPW was $50\mu m$, with the centre track having a width of $30\mu m$ and gaps of $10\mu m$ to the ground plane on each side, before being linearly tapered to a width of $1.66\mu m$ over a distance of $500\mu m$. The centre track-to-gap ratio was maintained at 3:1 to avoid impedance discontinuities. Cross sections of the electric field were plotted at regular points along the tapered CPW, and the field intensity profiles extracted. The confinement area was defined as the area where the field is within an order of magnitude of the maximum value. Confinement area and the average field in this area are plotted against taper width in Fig. 1.

III. FABRICATION

300 nm of low temperature grown Gallium Arsenide (LT-GaAs) was grown on a Gallium Arsenide substrate at a temperature of $205^\circ C$ with a 100 nm release layer of AlAs in-between. It was annealed at a temperature of $550^\circ C$ in order to increase its dark resistivity [3]. Black wax was melted on to protect the LT-GaAs surface and the edges were cleaned using a non-selective fast sulphuric acid etch ensuring that the AlAs boundary layer was fully exposed. A slow HF acid etch was then performed for $\sim 24$ hours at $3^\circ C$ to separate the LT-GaAs and black wax from the GaAs substrate. The LT GaAs was then transferred onto a quartz substrate, ensuring that there was a thin film of water between the LT-GaAs and the quartz. Next, the device was heated at $80^\circ C$ for two hours to allow the water film to evaporate without boiling while also softening the black wax to allow for conformal adhesion. The black wax was then removed in trichloroethylene. Finally the device was baked at $250^\circ C$ at a pressure of 30 mBar for 15 hours to ensure total dehydration and improve LT-GaAs adhesion to the substrate.

Electron beam lithography was used to define a narrow taper region with optical lithography used to define the rest of the waveguide and photoconductive switches. In both cases Ti/Au was evaporated, with thicknesses of $(5/100)$nm for the
Transmission of THz radiation through tapered CPWs was demonstrated experimentally and modelled in HFSS. Transmitted powers follow a similar functional form between the model and experiment. The high field confinement, associated with the ability to guide THz radiation via lithography defined waveguides opens the possibility of direct sensing or excitation of submicron electronic/spintronic devices.

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REFERENCES


