Semiconductor surface plasmons: a route to terahertz waveguides and sensors

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I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

Edmund Keith Stone
2012

I would like to dedicate this thesis to Phyllis Mary Hamblen my loving gran who passed away during my second year.

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Abstract

The terahertz regime has until recently been some what neglected due to the difficulty of generating and measuring terahertz radiation. Terahertz time domain spectroscopy has allowed for affordable and broadband probing of this frequency regime with phase sensitive measurements (chapter 3). This thesis aims to use this tool to add to the knowledge of the interactions between electromagnetic radiation and matter specifically in regard to plasmonics.

This thesis covers several distinct phenomena related to plasmonics at terahertz frequencies. The generation of terahertz radiation from metal nanoparticles is first described in chapter 4. It is shown that the field strength of the plasmon appears to relate to the strength of the generated field. It is also shown that the power dependence of the generated terahertz radiation is not consistent with the optical rectification description of this phenomenon. An alternative explanation is developed which appears more consistent with the observations. A simple model for the power dependence is derived and compared to the experimental results.

In chapter 5 the parameters that make good plasmonic materials are discussed. These parameters are used to assess the suitability of semiconductors for terahertz surface plasmon experiments. The Drude permittivity of InSb is measured here, leading to a discussion of terahertz particle plasmons in chapter 6. Finite element method modelling is used to show some merits of these over optical particle plasmons. This also includes a discussion of fabrication methods for arrays of these particles.

Finally, chapter 7 is a discussion of so called spoof surface plasmons. This includes some experimental work at microwave frequencies and an in depth analysis of open ended square hole arrays supported by model matching method modelling. Perfect endoscope effects are discussed and compared to superlensing. The thesis ends with a brief conclusions chapter where some of the ideas presented are brought together.

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Definitions

FEM	Finite element method
FIB	Focussed ion beam
$InSb$	Indium antimonide
SEM	Scanning electron microscope
SPP	Surface plasmon polariton
TE	Transverse electric (s-polarised)
$THz - TDS$	Terahertz time domain spectroscopy
TM	Transverse magnetic (p-polarised)

$Microwave\ regime$	$1 \rightarrow 200$ GHz
$Optical/Visible\ regime$	$300 \rightarrow 1000$ THz
$Terahertz\ regime$	$0.2 \rightarrow 2$ THz