Electromagnetic Wave Propagation Through and Reflection from Metal Nano Stripes Fabricated with Femtosecond Laser Ablation

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Electromagnetic wave propagation through and reflection from grating-like structures is one of the very fundamental and most studied subjects both in electromagnetics and optics. Several theoretical models and numerical solvers have been developed in order to solve this problem as efficiently and accurately as possible for different applications. In this work we experimentally study such phenomenon on metal nano stripe arrays fabricated with femtosecond laser ablation and compare our experimental findings with a full-wave time domain electromagnetic solver.

In our experiments, we use a chirped-pulse amplification system producing 550-fs pulses at 1 kHz repetition rate, at a center wavelength of 1030 nm. The third harmonic of the laser is generated through consequent second harmonic and sum-frequency generations. The laser energy is controlled with a waveplate and a polarizer. Gaussian laser output beam is converted to a Bessel beam with a 40°-base angle axicon. The sample is scanned under laser illumination by a piezo stage. By decreasing the incoming laser average power, we are able to ablate stripes as narrow as 125 nm on thin gold film coated substrates. By changing the distance orthogonal to ablation direction, micro- and nano-slit arrays are fabricated with different periods.

In the second part, we build transmission and reflection spectroscopy setups to characterize the fabricated structures. A tungsten-halogen lamp is used as a light source, which is focused into an optical fiber. Fiber output, collimated by a microscope objective, goes through a Glan-Taylor polarizer, and illuminates the samples. The illuminated samples are then imaged by another microscope objective. At the image plane, an iris is used to pass only the image of the array of interest. Finally, another objective is used behind the iris, to focus the transmitted/reflected light onto the fiber of the spectrometer.

In the last part, we compare our experimental results with a commercial full-wave solver (Wavenology from Wave Computation Technologies, Inc., Durham, NC). Experimental results agree well with the numerical results and they reveal the existence of two separate surface plasmon resonance modes occurring at the metal-air and metal-glass interfaces. The existence of double surface plasmon resonance modes is verified with additional experiments, theoretical and numerical studies.