Comparative study of the excitation of surface plasmon-polaritons with surface structures

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Abstract

We study the excitation efficiency of Surface Plasmon-Polaritons (SPPs) by surface structures illuminated by focussed beams. We consider surface features like steps, grooves and angled steps, and calculate efficiency maps for two different infrared wavelengths as functions of the parameters that define the structures. Our calculations show that long gratings can be good absorbers of the incident light but they are not necessarily efficient couplers to SPPs.

We also explore the possibilities of improving the coupling efficiency using periodic structures consisting of a small number of rectangular grooves. We design compact couplers that are about 4 wavelengths in length and can couple about 50% of the incident light into a directional SPP.

Structures studied

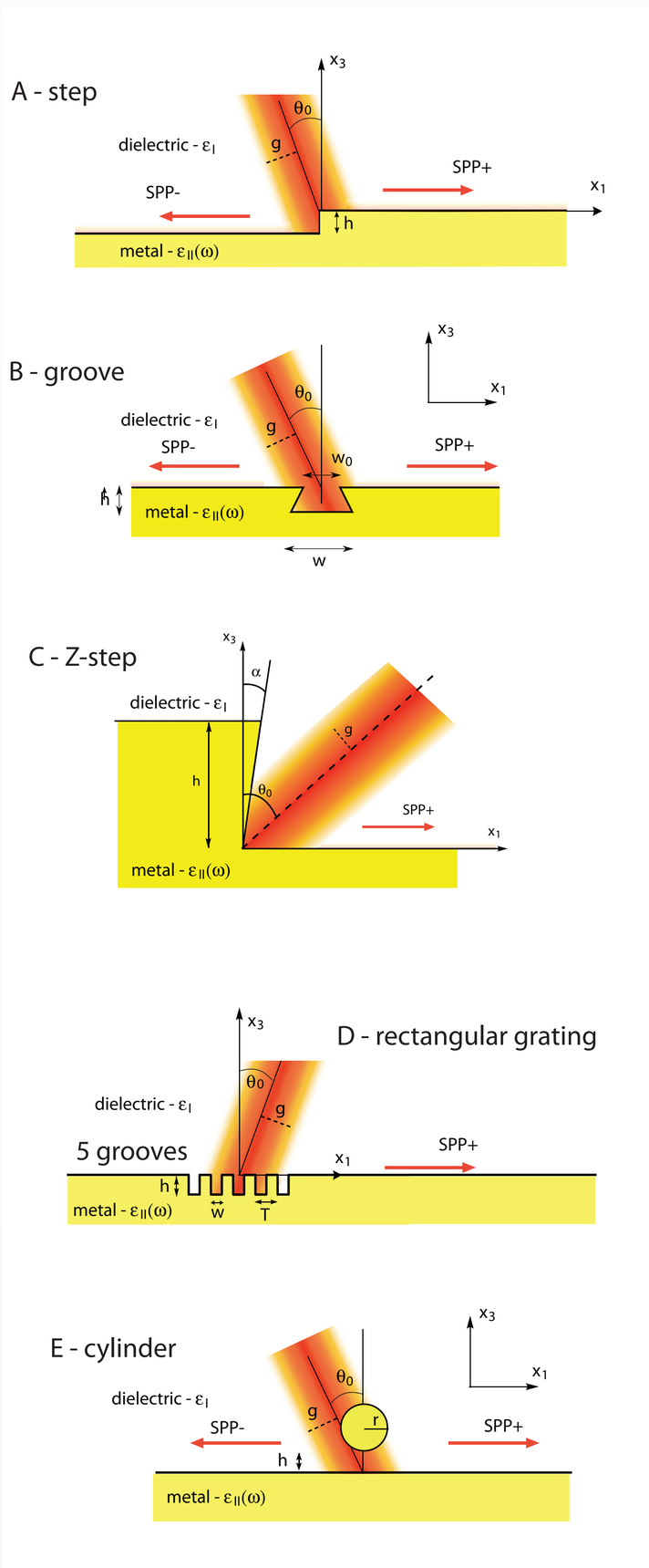


Illustration of the structures studied.

The coupling efficiency

The field of a SPP

$$H_2^{I,II}(x_1,x_3) = H_0 e^{ik_{sp}x_1 + i\alpha_{I,II}(k_{sp})x_3},$$

where $\alpha_{I,II}(k_{sp}) = \sqrt{\epsilon_{I,II}(\omega/c)^2 - k_{sp}^2}$.

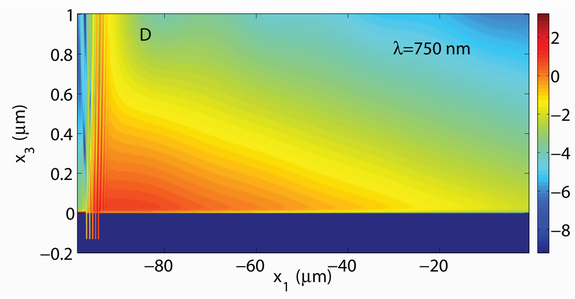
Defining

$$P^I = L_2 \int_0^\infty S_1^I dx_3\,, \quad P^{II} = L_2 \int_{-\infty}^0 S_1^{II} dx_3,$$

where $S_1^{I,II}$ represents the x_1-component of the Poynting vector, we can write the efficiency as

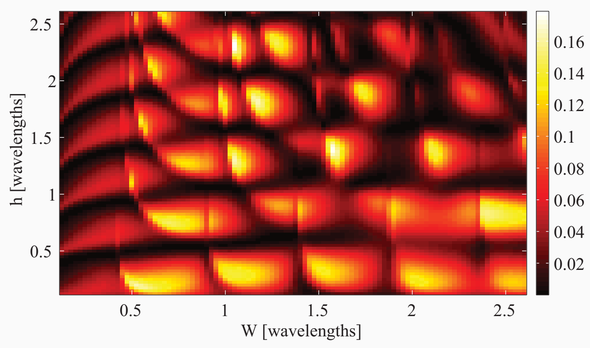
$$\eta = \frac{P_1^I + P_1^{II}}{P_{inc}}.$$

Here, P_{inc} is the power of the incident beam.



Excitation of SPPs by structure D and a wavelength $\lambda = 0.750\,\mu m$.

Calculations of the excitation efficiency

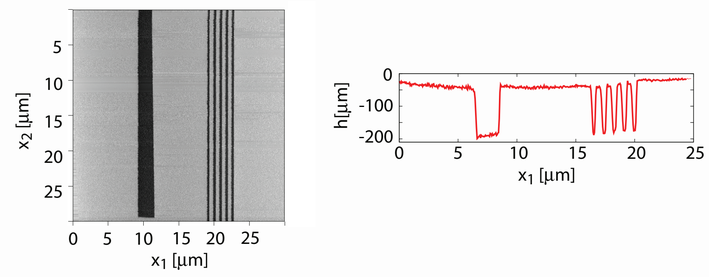


Excitation efficiency for a rectangular groove as a function of its defining parameters ($w = w_0$). $\theta_0 = 30°$, $\lambda = 0.750\,\mu m$, and $g = 3\lambda$.

structure	parameters	efficiency
A	$h = 0.18\,\lambda$ $\theta_0 = 30°$	0.06
B	$h = 2.3\,\lambda$ $w = w_0 = 1.05\,\lambda$ $\theta_0 = 30°$	0.17
C	$\alpha = 18°$ $h = 1.9\,\lambda$ $\theta_0 = 45°$	0.34
D	$h = 0.175\lambda$ $w = 0.425\lambda$ $T = 0.853\lambda$ $\theta_0 = 6.5°$	0.45
E	$r = 0.6\lambda$ $\theta_0 = -35.0°$	0.20

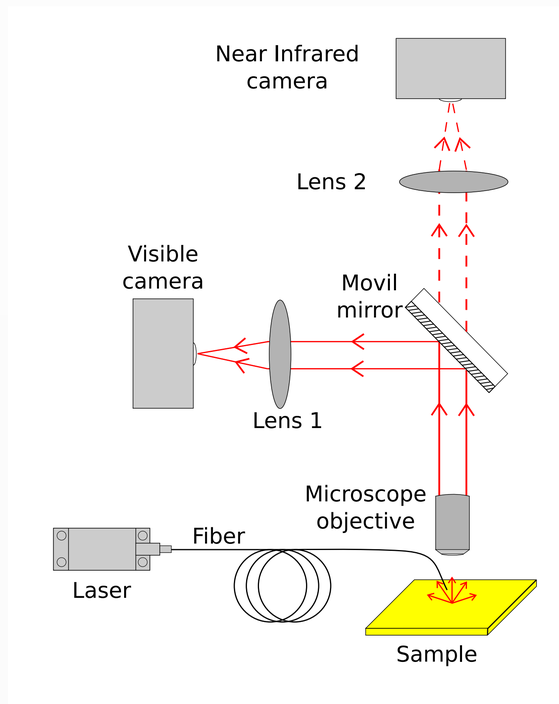
Maximum efficiencies calculated for gold surfaces and a wavelength $\lambda = 0.750\,\mu m$.

Sample fabrication by EBL

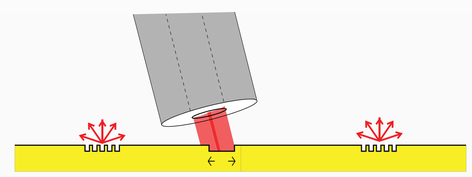


AFM image of a fabricated sample and the estimated profile.

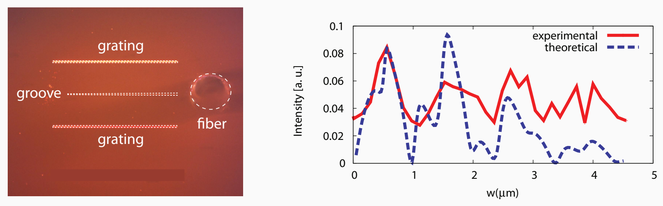
Experimental results



Schematic diagram of the experimental setup.



Visualization of the efficiency of excitation.



Excitation as a function of the width of a groove.

Summary and conclusions

We have studied the efficiency of excitation (SPPs) by surface structures illuminated by focussed beams.

- With angled steps, the efficiencies can reach as much as 35%.
- Rectangular grooves lead to efficiency maps that reflects the resonances of the groove. Efficiencies of 17% can be obtained for some angles of incidence.
- Structures consisting of five grooves can couple as much as 45% of the incident light into a directional SPP. The coupling efficiency is fairly tolerant to changes in the design parameters.