

reflectance from a bare nanoplasmonic array to that covered by a protein adlayer, where both reflectances are appropriately angle-averaged, according to Eq. (3).

We note that our experimentally tuned grating-coupled arrays previously measured with an FTIR microscope [1] display similar linewidth and peak reflectance to that of Array II in this study. Thus, such geometry may represent the best compromise for the diffraction-coupled enhancement that can be obtained with an extended angular cone illumination. On the other hand, better resonance matching and, perhaps, better detection sensitivity may be achieved with laser illumination mid IR sources, such as quantum cascade lasers (QCLs) [29].

5. Conclusions

Using oblique angle-of-incidence simulations, we have analyzed the response of plasmonic diffractively coupled nanoarrays under irradiation conditions of a typical Schwarzschild objective.

We find that arrays that are perfectly tuned at normal incidence to the diffractively coupled condition undergo substantial change in reflectivity and near field enhancement even for modest departures from the normal irradiation. Array detuning is caused by increased dephasing of coherent oscillations for increased angles of incidence, manifested by drop in resonant peak intensity, both in the far- and the near-fields, but only a modest peak shift. These detuning effects lead to a 20% drop in reflectance resonance for an objective illumination at 0.4 to 0.5 NA as compared to the normal incidence illumination. On the other hand, an array that is slightly detuned from the normal-incidence grating coupling condition undergoes only a modest change in response for a non-normal incidence irradiation with a Schwarzschild objective. The peak reflectance and linewidths of such arrays are consistent with the nanoplasmonic arrays that have been empirically optimized utilizing a commercial FTIR microscope [1]. An explicit calculation of relative absorbance enhancement of these two arrays should consider a response of a protein-covered surface.

The detuning of plasmonic arrays for non-normal incidence suggests that numerical optimization strategies of such structures must consider the exact irradiance profile of illumination and collection optics instead of relying on normal incidence results. The results also suggest that interrogation of these plasmonic arrays with collimated beams such as obtained from a quantum cascade laser source [29] may allow additional sensitivity improvement of the plasmonic arrays beyond what is currently realizable with microscope objectives.

Acknowledgments

The Lincoln Laboratory portion of this work was sponsored by ASD(R&D) under Air Force contract no. FA8721-05-C-0002. Opinions, interpretations, conclusions and recommendations are those of the authors, and do not necessarily represent the view of the United States Government. The Boston University portion of this work was supported in part by an NSF MRI award (SE) and an NSF SGER award (HA), and the Boston University Photonics Center and Army Research Laboratories. One of the authors, AM, gratefully acknowledges support from MIT Lincoln Laboratory.