Thesis subject: Optical coatings

Name of the laboratory: Institut Fresnel

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Subject’s title: Variable thin-film filters for hyperspectral imaging

Multispectral imaging and more generally hyperspectral imaging is a key technology for space studies as it allows at the same time imaging a scene and spectrally analyzing it. However, as of today, there is no mature technology to provide compact, high performance and dense hyperspectral components. In this Ph.D. thesis we propose to develop variable thin-film optical filters using plasma assisted reactive magnetron sputtering (PARMS) technology. These filters exhibit a change of the spectral properties along one spatial dimension. When combined with a CCD camera, they allow hyperspectral imaging through pushbroom technique.

Actually, over the past few years, we have shown that while PARMS technology is the key technology for producing high performance complex filters, it can be tuned to provide variable filters with similar overall performances but spatially varying spectral properties. By inserting a gradient mask in between the sputtered targets and the substrates to be coated, it is possible to generate a gradient of thickness, and therefore a change of spectral properties along one direction. We have demonstrated through French-space Agency-funded projects that this technology is compatible for both visible and SWIR regions. However, we have faced several limitations: low deposition rate, cosmetics issues, limited spectral ranges and gradient slopes.

Within this Ph.D. thesis, we aim at fixing these limits in order to provide a mature technology that can be implemented for future missions. At first, we will adapt this technology to the new PARMS machine (Bühler HELIOS 800) that was installed summer 2024 at institute Fresnel, in order to be compatible with the technology that is used with the main actors of the European thin-film industry and therefore allow possible transfer to industry at the end of the project if required. This will include designing the proper mechanics and controls in order to produce the thickness gradients as well as implementing new masks alignment procedures and gradient calibrations. Another key advantage to move to this new technology will also to benefit from the latest improvement that have been made to the machine in order to minimize the number of defects generated during the deposition of layers. Similar approaches will also be developed and implemented on the gradient masks in order to operate in optimal deposition conditions.

A second key development will be to develop the optimal deposition parameters of high and low refractive index materials as well as choosing the one that better answer the needs for variable filters. By adding the gradient masks, rates are severely decreased, making the fabrication of such filters very long (several tens of hours) and expensive. By adjusting the materials and deposition parameters (pressure, power, use of several magnetrons), we expect to increase the deposition rates while maintaining optimal spectral performances.

In addition to these technological development, we plan to develop proper metrology for the local measurement of the spectral properties of such filters. We aim a measuring the spectral performances with down to 20 micron, if possible 10 micron spatial resolution and 1 nm spectral resolution. This step will be critical in order to analyze the experimental results and that way improve the developed technology

Finally, the last objective will consist in analyzing the different possible configurations of variable filters in order to cover broad spectral ranges with the variable filters: i.e. is it more efficient to cover a spectral range using several consecutive adjacent filters rather than a single thick and complex filter, and, if yes, how to efficiently combine those one into a single substrate. This analysis will require thin-film filters design, taking into account the spectral regions of interest as well as the detector sensitivity ranges. As a result, we will produce a tradeoff approach that will allow analyzing future project specifications and, ultimately minimize filter complexity and maximize the fabrication yield.

The candidate will work within the thin film research team of Institut Fresnel, both on numerical simulations and experimental demonstrations that will be carried out in cleanrooms. The candidate must have a Master in Science with good knowledge in optics, programming and if possible in optical thin films.

Bibliography :

T. Begou, F. Lemarquis, A. Moreau, F. Lemarchand, H. Reus, D. Arhilger, H. Hagedorn and J. Lumeau, "Application of static masking technique in magnetron sputtering technology for the production of linearly variable filters", CEAS Space Journal 14, 217–226 (2022).