Laboratoire des sciences de l'ingénieur
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**Subject: PhD proposal (French Govt. 3 yr doctoral grant)**

**Title: "**Study of super-resolution techniques for improving the lateral resolution in interference microscopy"

**PhD directors:** Paul Montgomery (Research Fellow) and Bruno Serio (Lecturer)

## Summary

One of the advantages of interference microscopy for non-contact characterisation of microscopic surface topography is the nanometric resolution along Z. With new applications in nanotechnologies, a higher lateral resolution is necessary. In far field optical microscopy the limit imposed by diffraction has been broken by techniques such as confocal microscopy, structured illumination microscopy (SIM) and STED 4π.

This research project aims at the study of the different techniques that would allow the improvement in the lateral resolution in interference microscopy so as to move towards a "nano-3D" measurement system having nanometric spatial resolution in all three directions X, Y and Z. One path to follow up first will be techniques using structured illumination such as in SIM. As well as super-resolution, other functionalities will also be considered, such as 3D microscopic surface profiling, automatic focusing or increasing the depth of field in optical microscopy. The use of theoretical simulation tools will allow the optimization of the structured light pattern and of the appropriate processing required. Other solutions for improving the lateral resolution, such as "sub-pixel" reconstruction techniques will also be considered. This work will be carried out within the context of a project for the development of an "Optical system for dermatological analysis by parallel imaging" proposed by the IPP team.

## Subject description:

One of the advantages of interference microscopy for the non-contact characterisation of surface topography is the nanometric resolution along Z. Such a high axial resolution is possible because of the precise measurement of the phase of the light [1]. On the contrary, the lateral resolution is limited by diffraction to a value of around λ/2, or about 0.3 µm in visible light.

With new applications in nanotechnologies and biotechnologies, a higher lateral resolution is necessary. In far field optical microscopy the limit imposed by diffraction has been broken by techniques such as confocal microscopy, structured illumination microscopy (SIM) [2] and STED 4$\pi$ (stimulated emission depletion) [3].

This research project aims at the study of the different techniques that would allow the improvement in the lateral resolution in optical microscopy for use in interference microscopy so as to move towards a “nano-3D” measurement system having nanometric spatial resolution in all three directions X, Y and Z. One path to follow up first will be techniques using structured illumination such as in SIM. With this technique, a periodic structured light pattern having a period that is inferior to the lateral resolution of the imaging system is projected onto the surface of the sample. The high spatial resolution information of the sample that is normally unresolvable is made visible by moiré fringes resulting from the interference between the projected pattern and the fine structure of the sample surface [2]. In frequency space the high frequency information is displaced into the observable region by means of the moiré fringes.

As well as super-resolution, other functionalities will also be considered using SIM, such as for 3D microscopic surface profiling be means of resolved structured light patterns. The advantages would be to eliminate the need for axial scanning to measure the surface relief. It would also be possible to develop a system for obtaining automatic focusing or increasing the depth of field in optical microscopy. The use of theoretical simulation tools will allow the optimization of the structured light pattern and of the appropriate processing required. Other solutions for improving the lateral resolution, such as "sub-pixel" reconstruction techniques will also be considered. This work will be carried out within the context of a project for the development of an “Optical system for dermatological analysis by parallel imaging” proposed by the IPP team.

**References**

[1] A. Benatmane, P.C. Montgomery, E. Fogarassy, and D. Zahorsky, *Interference microscopy for nanometric surface microstructure analysis in excimer laser processing of silicon for flat panel displays*, Applied Surface Science, 208-209, pp. 189-193, 2003.

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[3] Bewersdorf J, Schmidt R and Hell SW, *Comparison of I5M and 4Pi-microscopy*, Journal of Microscopy, 222, Pt 2, pp. 105-117, 2006.

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