The phenomenon of the Arago-Poisson bright diffraction spot is well known. Perhaps lesser known is the fact that one can "drill a hole" in such a spot with helical laser beams. This is the subject of the project. Depending on the option chosen, it may require an extension of the spectral techniques covered in the course.

Project subject:

Set up and execute BPM-based simulation study of the experiment described in the attached paper by O. Emile et al.: *Dark zone in the centre of the Arago-Poisson diffraction spot of helical beams*, EPL **101** (2013) 54005.

Project versions: Students can choose to implement one of the following BPM approaches

- **A** Computational domain in two transverse dimensions, without assumptions about the symmetry of the problem. Students can choose any particular BPM technique deemed appropriate. This option, while utilizing a more general approach, will require more computer power.
- **B** Radially symmetric treatment, with the angular dependence implicitly accounted for through the use of appropriate-order Hankel transforms. This option requires a simple generalization of the DHT technique discussed in the class.

Tasks:

- Set up the discretized equations to be simulated. Describe the geometry and how it reflects in the method chosen. Decide whether you are going to simulate also the beam preparation, which requires modeling the vortex phase plate, and lenses. You may opt to set up a vortex beam as you initial condition.
- Implement the chosen BPM method. According to the paper, vectorial effects are unimportant, so it will be sufficient to use a scalar BPM.
- Demonstrate that your simulation tool can reproduce key findings described in the paper.
- Discuss numerical and modeling issues you encounter — for example, you can provide a "how-to" that would help your fellow student to use your "product" as an Exercise Package.
- Submit a report in the pdf format, together with all sources and input files needed to reproduce the simulation runs and/or results described in the report.

Optional add-ons:

- It is acceptable to scale dimensions of the problem if you find that simulations are too demanding for the hardware used. As an extension, you may attempt to perform a simulation with parameters nominally matching those of the experiment.

Notes:

This project choice involves extension of the material covered in the class. Several Exercise Packages dealing with simulation of the Poisson's bright spot can be used and students can re-use parts of those codes.

If you decide to go with Hankel-transform based propagator(s), you will have to generalize your codes for DHT written in the class. In particular, zeros of higher-order Bessel functions will be needed. Do not write a code to calculate them - they should be obtained from an appropriate library, or imported in the same form as we did in our exercises (for Matlab).

Potentially useful sources:

EP06-DHT-BPM, EP05-2D-FFT-BPM-Spot-of-Arago, EP052-2D-Spectral-BPM-Beams