A BESSEL FUNCTION BASIS FOR THE CONTROL OF PSF SIDELOBES

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Point Spread Function (PSF) engineering by pupil filters is a relevant technique in several applications, such as confocal microscopy, optical data storage and astronomy. Circular-symmetric filters have been usually preferred for the ease of their fabrication and analysis. A seminal study on such filters was performed by Toraldo [1]. Sheppard [2] introduced the parabolic approximation of the PSF, which has been used in most methods for designing amplitude filters. More recently, this parabolic approximation was generalized for general complex filters [3], allowing in the last years a fast development of phase-only and hybrid filter designs. In spite of the success of these methods, the parabolic approximation has some disadvantages, because a second order expansion lacks some precision and can not take the sidelobes into account, as needed in many applications. Thus, a new design procedure, not based on the parabolic approximation, is shown. In this new method, the PSF is expanded in the basis of the first order Bessel functions. Now, it is not necessary to use the approximated PSF for the filter design process, what, consequently, produces more precise results. Furthermore, figures of merit taking into account the PSF sidelobes can be easily included. Although it is possible to build any annular filter by this procedure, we use binary filters with only two possible values of the phase: 0 and $\pi$. Such filters allow to attain transverse superresolution with moderate sidelobes and high Strehl ratio. The designed filters can offer slightly better results than the best hybrid filters [4]. In fact, we show that they allow a very high superresolution value (near 60% of the core width) with a core that stands out over its side lobes.