The role of optical processing in PIV

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This symposium is commemorating the 1984 PIV records from the low-turbulence wind tunnel at DLR in Göttingen. The double-exposure photographic images from this campaign had to be processed by inspecting the Young's fringes produced by diffraction of a laser beam interrogating small areas in the photo. At that time, there was no reasonable alternative to this kind of optical processing. The implementation of an optical device was essential for the success of the method. Gradually, with the progress of electronic image acquisition and digital data processing the optical methods offered for the evaluation of PIV records became less significant. Looking back, they can be considered auxiliary or even just optional tools. The present paper explores the historical development of the role optics played in the interrogation of PIV images by briefly recalling the most important approaches proposed, placing them in the technological scene of the time and identifying essential influences that governed the development.

The first decade is characterized by efforts to economize the fringe method by more effective extraction of fringe orientation and spacing. While most techniques aim at a digital output of the final displacement values, quite a few make use of auxiliary optical components. These serve to avoid some cumbersome computations like in spatial integration or image rotation. The initiating 1984 measurements at the Göttingen wind tunnel were mainly carried out to explore the suitability of the new technique under wind tunnel conditions. In addition a novel optical processing scheme called large-area-interrogation was tested. In this study, the degree of turbulence was determined from the space-dependent visibility of the overall fringe pattern thus bypassing the accumulation of point-wise interrogation data. Other optional proposals were to reduce the large portion of interrogation time spent in scanning the interrogating laser over the PIV transparency. Simultaneous interrogation of many spots by a light field from a 2-D array of many small lenses served this purpose. Finally, spatial-frequency filtering was applied for generating velocity contour lines to provide a kind of flow field visualization of the complete observation area. This was achieved purely by optical means.

This latter method points towards even more challenging solutions that were pursued to obtain the displacement of a particle cluster by applying optical spatial correlation. The spacing of the side peaks in the autocorrelation of the light intensity in the interrogation area yields the wanted displacement vector. Autocorrelation requires a sequence of operations: a first Fourier transformation, modulus-square operation and another Fourier transformation. All Fourier transformations can be performed easily by optics. The procedure in between, however, requires transcribing the fringes pattern onto a spatial light modulator. The availability of various types of modern optical components promoted as well as limited the performance of these correlators. Efforts in the field finally led to sophisticated three-dimensional correlation architectures.

Optical procedures that were originally essential for the performance of PIV faded when the digital techniques expanded. It is interesting to analyze when and how researchers reacted to the competing methods that were fueled by technological needs beyond PIV requirements. Many an ingenious optical invention became obsolete and the attention turned from physics more to technology and computing. A similar development is presently seen in particle holography.