The state of the art in interference microscopy: Modern techniques for geometric form, surface texture and areal structure analysis

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1. A tradition of precision in 3D measurements

Interference microscopy makes use of optical coherence phenomena to determine form, roughness, transparent film structure, and optical properties of microscopic surface areas. Visual interferometers based on the observation of interference fringes date from the early 20th century [1], while computer automated form and roughness microscopes appeared in the 1980's [2]. A significant advance was the invention of coherence scanning interferometry (CSI), first as a high-precision technology for semiconductor inspection [3], then as a general-purpose tool capable of viewing a large range of surface textures, including those rough enough to generate seemingly random speckle patterns [4].

The most common CSI configuration today is a custom microscope platform with interchangeable interference objectives of the Michelson or Mirau type, together with an electronic camera and a means to scan the objective to vary the distance to the sample [5]. Unlike digital holographic microscopes, in most cases CSI systems synchronously vary the optical path difference and the objective focus. Interference fringes form at the zero path length difference, which is also the position of best focus, resulting in an indication of the local surface height at high lateral resolution. A close cousin to CSI is full-field, *time-domain* optical coherence tomography using microscope optics [6].

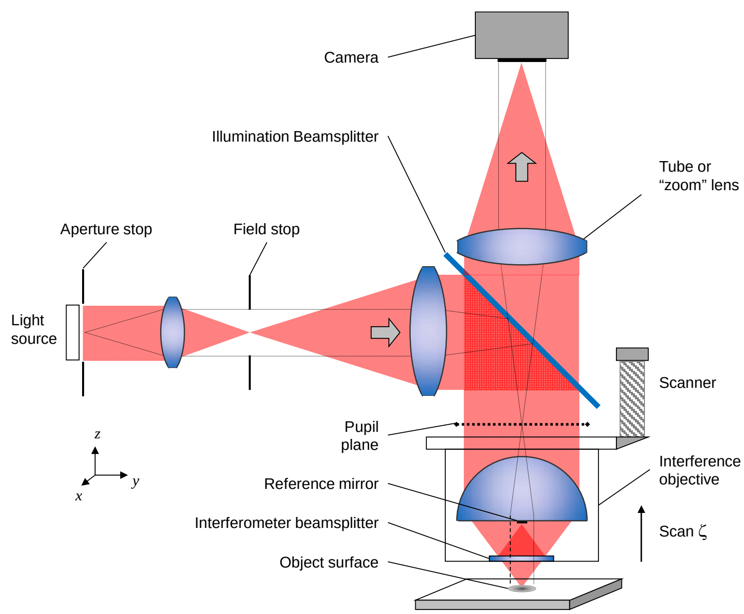

Fig. 1. Common configuration of a modern interference microscope employing a Mirau type interference objective. Most often, the interference objective is interchangeable with other types and magnifications. Data acquisition involves a mechanical scan of the objective while recording a sequence of interference patterns at the camera, later to be interpreted by a computer to generate final 3D images.

2. Expanding range of applications

CSI microscopy has played a leading role in the measurement of form, waviness and roughness on surface areas from 0.05 to 5 mm in diameter (Fig. 2), with a height uncertainty that in some cases is well below 1nm [7]. The technique has evolved to a multi-functional platform for surface structure analysis, including the measurement of transparent films [8]. Drivers for this evolution include the increased complexity and shrinking feature size of high-volume production components, and the continuously increased importance of surface geometry and texture in many economic areas [9]. Recent advances include increased accommodation of steep slopes and difficult materials (Fig. 3) [10], new objectives for large fields of view [11], and methods for parameter metrology of optically-unresolved surface structures [12]. Many of these new technologies rely on advanced modeling of the interference phenomenon, including a deeper understanding of how wavefronts are modulated by surface details and material properties [13].

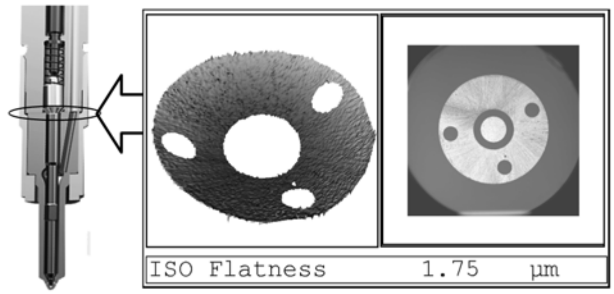

Fig. 2: 3D topography image of a sealing surface in a diesel fuel injector [14]

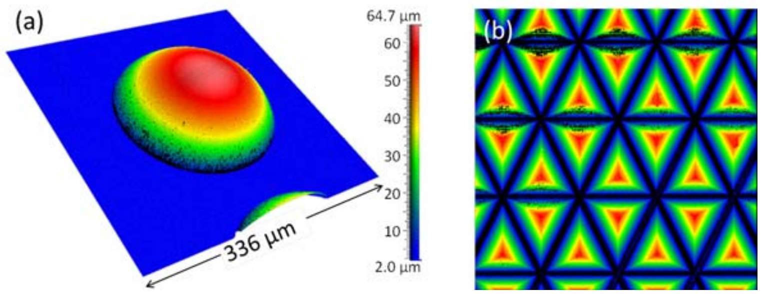

Fig. 3: Measurements of (a) polymer micro-lens (b) retroreflector array [10].

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