FORTY LIGHT YEARS OF MICROSCOPY

Colin J. R. Sheppard
School of Chemistry, University of Wollongong NSW 2522, Australia
Istituto Italiano di Tecnologia, via Morego 30, Genova 16163, Italy
E-mail: colinjrsheppard@gmail.com
https://www.researchgate.net/profile/Colin_Sheppard

Our first laser scanning microscope at Oxford University was operational in January 1974 [1]. In the subsequent years, the Oxford Group investigated confocal microscopy in transmission, reflection, fluorescence and interference modes [2]. The first images from scanning second harmonic generation microscopy were published [3]. We also developed differential phase contrast (DPC) microscopy. In my final year before moving to Sydney, I proposed what is now known as image scanning microscopy (ISM), which achieves confocal resolution with greatly increased signal level [4].

The theory of imaging in different types of partially coherent microscope including confocal microscopy with a finite sized detector, and the spinning disk microscope was developed. The special cases of imaging of weak and slowly varying objects were identified, and the resultant weak object and phase gradient transfer functions (WOTF and PGTF) for brightfield, DPC and differential interference contrast (DIC) microscopes presented. The theory of three-dimensional (3D) imaging in confocal and conventional systems was investigated.

From 1977, we investigated the application of Bessel beams in confocal microscopy. The propagationally invariant nature of Bessel beams was identified, and the Bessel-Gauss beam introduced [5].

In Sydney (1989-2003), activities included investigation of the 3D transfer function, fibre-optic confocal microscopy, and signal-to-background and signal-to-noise ratios in microscopy. A theory of confocal reflection based on scattering by the sample was developed, and applied to fractal objects. A full-field OCT system was built.

In Singapore (2003-2012), a full-field version of DPC was developed. Phase imaging by the transport of intensity equation was investigated. A theory of imaging in partially coherent microscopes based on the Wigner distribution function was studied. The focal modulation microscope (FMM) was developed, extending the penetration depth of confocal microscopy [6].

In Genoa (2012-2017), work has continued on ISM. Application of the 3D transfer function to optical propagation has been investigated. The theory of polarization, and its application in microscopy, has been studied.

I acknowledge the contributions of many collaborators. I have published papers together with over 300 coauthors, so it is not possible to mention them by name here.

1. R. Kompfner, C. J. R. Sheppard, D. Walsh, A. Choudhury, J. N. Gannaway, and P. G. Hale, "Applications of Quantum electronics; Part 1, the scanning optical microscope," Oxford University Engineering Laboratory Report No. 1183177, 1975.
2. C. J. R. Sheppard, "15 years of scanning optical microscopy at Oxford," Proc. RMS **25**, 319-321 (1990).
3. J. N. Gannaway and C. J. R. Sheppard, "Second harmonic imaging in the scanning optical microscope," Opt. and Quantum Elect. **10**, 435-439 (1978).
4. C. J. R. Sheppard, "Super-resolution in confocal imaging," Optik **80**, 53-54 (1988).
5. C. J. R. Sheppard and T. Wilson, "Gaussian-beam theory of lenses with annular aperture," IEE J. Microwaves, Optics and Acoustics **2**, 105-112 (1978).
6. N. G. Chen, C. H. Wong, and C. J. R. Sheppard, "Focal modulation microscopy," Optics Express **16**, 18764-18769 (2008).