BIOGRAPHICAL SKETCH

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NAME: Cogswell, Carol J.

eRA COMMONS USER NAME (credential, e.g., agency login): CAROLCOGSWELL

POSITION TITLE: Research Professor in Electrical, Computer and Energy Engineering

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
University of Oregon, Eugene	B.S.	1969	Biology
University of Oregon, Eugene	M.S.	1971	Biology
University of Oregon, Eugene	M. Arch.	1979	Architecture

A. Personal Statement

I have several decades of experience in the field of optical microscopy and imaging, specifically in designing and fabricating new instruments that target live-cell biological applications. In the past, my research groups have been major players in the field of confocal microscopy, developing one of the first experimental confocal transmission systems and the first confocal DIC microscope. I have also supervised several projects in the field of computational imaging, including point spread function engineering to extend the capabilities of biological microscopes. In more recent years, my research team has focused on exploring new ways to optically control the phase of the light that forms the microscope image, with the result being that we can now encode much more information into a single image than is possible with any commercial microscope. This has led to such breakthroughs as being able to see an entire cell in focus (extended depth of field) in a single high-resolution image, and to overcome the long-accepted diffraction limit barrier to resolution. In the process of constructing experimental microscopes for testing and evaluation by our biological collaborators, we have had to overcome many problems which are particularly difficult when attempting to design and develop high-resolution imaging instruments. The result is we have become experts in such things as point spread function engineering and developing new computational methods for processing images, all of which are directly relevant to the proposed microscope development project.

An important strategic factor for conducting my research at CU is its strong links to several commercial optics R&D companies in the area. At present, I am beginning a new collaboration with Intelligent Imaging Innovations (3i) Inc., headquartered in Denver, to explore ways to improve some of their fluorescence imaging microscope systems. In the past, I have had a joint NIH SBIR grant with Boulder Nonlinear Systems Inc., to develop an automated quantitative DIC microscope using novel liquid crystal devices developed by the company. This is in addition to my former joint appointment as a research scientist at CDM Optics/OmniVision (in the University's nearby research park) which provided me first-hand experience in how to successfully convert new instrument design ideas into tested products and bring them to the marketplace.

B. Positions and Honors

Positions and Employment

1969 – 1989: Assistant Director and Research Assistant / Research Associate, University of Oregon, Bio-Optical Laboratory (core user facility for light microscopy and imaging science)
1990 – 1993: The Slade Research Fellow, Physics, University of Sydney, Australia
1993 – 2000: Senior Lecturer (tenured), Physics (Physical Optics), Univ. of Sydney, Australia

1995 – 2000: Deputy Director, Australian Key Centre for Microscopy and Microanalysis, University of Sydney, Australia
2000 – 2004: Adjunct Research Professor, Dept of Electrical and Computer Engineering, University of Colorado at Boulder (half time appointment)
2000 – 2008: Senior Researcher, Microscope Development, CDM Optics, Inc. Boulder, CO (half time appointment)
2005 – present: Research Professor, Dept of Electrical, Computer and Energy Engineering, University of Colorado at Boulder (half time appointment until 2009, then full-time)

Other Experience and Professional Memberships

1988 and Summer, 1989: Visiting Academic, University of Oxford, U.K. (Collaborative research in confocal microscopy, with C. J. R. Sheppard and T. Wilson, Department of Engineering Science)
1988 – present: Member of the International Advisory Committee for the Focus on Microscopy annual conference series
1992 – 2018: Chair of the SPIE Annual Conference on *3D and Multi-Dimensional Microscopy: Image Acquisition and Processing,* Photonics West Symposium, San Francisco, CA
June and August, 1997: Visiting Academic, BMIRR, Wadsworth Center, Albany, NY. (Collaborative research in live-cell DIC and GFP-labeled microscopy and laser microsurgery with C. Rieder)
July 1997: Visiting Academic, Marine Biology Laboratory, Woods Hole, MA. (Confocal microscopy research)
Summer, 1998 and 1999: Visiting Academic, University of Colorado, Boulder, CO. (Collaborative research in extended-depth-of-field optics as applied to microscopy, with W. T. Cathey, Department of Electrical and Computer Engineering)
July 2005: Invited member of the National Institutes of Health (NIH) Review Panel for "Microscopy and Imaging" Grant Proposals

Honors

1988: Promoted to Research Associate by Vice President for Academic Affairs, Univ. of Oregon, in recognition of academic achievement equivalent to a PhD
1990-93: Awarded the Slade Research Fellowship in Physics, Univ. of Sydney, Australia
2000-01: Recipient, National Science Foundation POWRE (Professional Opportunities for Women in Research and Education) Career Advancement Award
2007: Elected to Fellow of the International Society of Optical Engineering (SPIE)

C. Contributions to Science

1. My early work in optical microscopy development was in the field of confocal laser scanning microscopy from 1988-98, first as a visiting scholar at Oxford University (in collaboration with Colin Sheppard) and later at the University of Sydney, School of Physics (Australia). My research teams were pioneers in exploring the feasibility of developing a confocal transmission DIC microscopy as well as investigating many questions related to resolution improvement in confocal systems. This early experience is applicable to the proposed new microscope development project that will, among other things, require implementing transmission laser scanning illumination technologies.
    a. Cogswell, C. J. and Sheppard, C. (1992) Confocal differential interference contrast (DIC) microscopy: including a theoretical analysis of conventional and confocal DIC imaging, *J. Microsc*. **165**, 81-101.
    b. Arnison, M., Cogswell, C., Smith, N., Fekete, P., and Larkin, K. (2000) Using the Hilbert transform for 3D visualisation of differential interference contrast microscope images, *J. Microsc.* **199**, 79-84.
    c. Kyan, M., Guan, L., Arnison, M. and Cogswell, C. (2001) Feature extraction of chromosomes from 3D confocal microscope images. *IEEE Transactions on Biomed. Eng.,***48**, 1306-1318.

2. A second major theme of my research is in the area of quantitative phase microscopy development, targeting biological imaging. My team was the first to demonstrate phase-shifting DIC mechanisms as a way to remove the errors inherent in traditional DIC images so that quantitative information could be recovered and displayed. The expertise my research team has gained from many years of instrument development in this field will be invaluable to the proposed super-resolution quantitative phase microscope project.
    a. Arnison, M., Larkin, K. G., Sheppard, C. J. R., Smith, N. I., and Cogswell, C. J. (2004) Linear phase

imaging using differential interference contrast microscopy, *J. Microsc.* **214**, 7-12.
   b. King, S. V., Libertun, A., Piestun, R., Cogswell, C. J. and Preza, C. (2008) Quantitative phase microscopy through differential interference imaging, *J. Biomed. Opt.* **13**, 024020-1-10.
   c. Preza, C., King, S. V., Dragomir, N. and Cogswell, C. J. (2011) Darkfield, phase and differential interference contrast (DIC) microscopy, invited chapter in "Handbook of Biomedical Optics," Boas, D. A., Pitris C., and Ramanujam, N., eds. Taylor & Francis, Boca Raton, pp. 483-515.

3. Other research relevant to this project is my work in Wavefront Coding which is a technology pioneered by my colleagues W.T. Cathey and E. Dowski at the University of Colorado and later at their company, CDM Optics, Boulder, CO. My work at the company focused on adapting novel point spread function techniques to high resolution microscopy systems by designing phase masks to encode extended depth of field (EDF) information into the microscope images. This encoded information was then recovered using specially-tailored algorithms based on deconvolution. In recent years, the ongoing problem of how to address the effects of noise that is a major issue in these EDF images has been the subject of my University of Colorado group's efforts into exploring numerical methods for modeling noise and implementing new digital processing routines for noise removal. The expertise gained in computational methods applied to optical microscopy imaging will be invaluable for this proposed microscope development project.
   a. Arnison, M. R., Cogswell, C. J., Sheppard, C. J. R., and Török, P. (2003) Wavefront coding fluorescence microscopy using high aperture lenses, invited chapter in *Optical imaging and microscopy: techniques and advanced systems*, P. Török and F.-J. Kao, eds., Springer-Verlag, Berlin, pp. 143-165.
   b. Dowski, E. R. Jr. and Cogswell, C. J. (2006) Wavefront coding interference contrast imaging systems, U.S. Patent no. 7,115,849.
   c. Zahreddine, R. N., Cormack, R. H. and Cogswell, C. J. (2013) Noise removal in extended depth of field microscope images through nonlinear signal processing, *Appl. Opt.* **52**, D1-D11.
   d. Zahreddine, R. N. and Cogswell, C. J. (2015) Total variation regularized deconvolution for extended depth of field microscopy, *Appl. Opt.* **54**, 2244-2254.

4. A final major research area that is applicable to the new microscope development project is our more recent work in super-resolution microscope development, that seeks to overcome the diffraction limit barrier using a combination of PSF engineering and numerical optimization image processing. This work was called "expanded point information content" (EPIC) microscopy and was shown to achieve super-localization imaging in all three dimensions at high speed, and from a single position of focus. After realizing the importance of scanning the sample to produce small sub-images, our EPIC microscope technology was expanded to include the potential ability to super-resolve three-dimensional continuous fluorescence objects. The knowledge gained in this ongoing research is the final ingredient that forms the basis for our belief in our ability to successfully develop the proposed new super-resolution 3D prototype microscope for live-cell imaging at speed.
   a. Zahreddine, R. N., Cormack, R. H. and Cogswell, C. J. (2012) Simultaneous quantitative depth mapping and extended depth of field for 4D microscopy through PSF engineering. Proc. SPIE, 822705–822705.
   b. Cogswell, C. J., Cormack, R. H. and Zahreddine, R. N. (2016) Engineered PSF for Simultaneous Extended Depth of Field Imaging and 3D Ranging, U.S. Patent No. 9,325,971.
   c. Yu, J., Becker, S., Folberth, J., Wallin, B., Chen, S., and Cogswell, C., (2017) Achieving superresolution with focused spot illumination and non-negative inversions. Submitted.
   d. Cogswell, C. J., Chen, S., Wallin, B., Herzfeld, U. C., Becker, S., Folberth, J., Zahreddine, R. N., Xing, J., Cormack, R. H., Tyler, J., Winey, M. and Yu, J.-Y. (2017) A new path to super-resolution microscopy. Submitted.

D. Additional Information: Research Support

Ongoing Research Support

NSF IDBR – Grant No. 1353444 2014-17
(C. Cogswell, PI, R. Cormack and M. Winey, Co-PIs, and A. Palmer, Faculty Associate)
An optically modified live-cell fluorescence microscope that generates video-rate, 3D imaging capabilities based on an innovative *"expanded point information content"* design

The goal of this project is to demonstrate how a new approach to optical design can convert existing live-cell fluorescence biological microscopes into fully 3D video-rate imaging instruments at a fraction of the cost and complexity of existing confocal and other 3D microscope designs.

Colorado Advanced Industry Accelerator – Proof of Concept Grant 2017-18
(C. Cogswell, PI, Jiun-Yann Yu, Co-Investigator, C. Monks, G. Redford, C. English, Key Members from industrial sponsor)
Reconfiguring 3i's commercial biomedical microscopes to achieve 3D super-resolution using CU's innovative illumination and computation designs

This project aims at designing and fabricating new phase plates used for a new type of super-resolution imaging method developed by the PI's group, and implementing the new phase plates with the existing lines of the sponsor's commercial microscopes.

Completed Research Support

University of Colorado Innovative Seed Grant 2014-15
(C. Cogswell, PI, Ute Herzfeld, Co-PI)
Combining a new point spread function scanning technique with custom image processing to overcome the limitations of biological microscopes for observing live-cell 3D dynamics.