

CURRICULUM VITAE

Part I: General Information

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Name: Robert H. Webb
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Education:

1955	AB	Harvard University (Physics)
1959	PhD	Rutgers University (Physics)

Postdoctoral Training:

1959-62 Molecular Physics, Stanford University,

Professional Appointments:

1962-68	Tufts University, Assistant Professor, Physics
1969-77	Block Engineering, Inc., Staff Scientist
1977-85	Eye Research Institute of Retina Foundation, Associate Scientist
1980-99	Harvard Medical School, Associate in Ophthalmology
1985-	Schepens Eye Research Institute of Retina Foundation, Senior Scientist Emeritus, 2007
1993-	Mass. General Hospital, Wellman Laboratory, Senior Scientist
1999-	Assoc. Prof, Department of Ophthalmology, Harvard Medical School
1999-	Assoc. Prof, Department of Dermatology, Harvard Medical School

Professional Societies:

American Association of Physics Teachers
Association for Research in Vision and Ophthalmology
Institute of Electrical and Electronic Engineers
Optical Society of America (Fellow, 1984-7 Chairman of Medical Optics Technical Group
& Member Technical Program Committee).

Community Service Related to Professional Work:

Serve on Study Sections, both NIH and NSF, about two per year until recently. Typical assignments are NIH (RR) Major Research Instrument and NSF Shared Instrument Grants, *ad hoc* on VIS-B and Vis-C occasionally.

Editorial and other Boards:

Optical Society of America	<i>Applied Optics</i> Topical editor 1998-1995
Optical Society of America	<i>Applied Optics</i> Review Committee
Optical Society of America	Technical Program Committee, 1998 Spring Topical Meetings

Awards and Honors:

1980	Contribution Award, Engineers in Med and Biology Soc (IEEE)
1981	IR100 Award for Scanning Laser Ophthalmoscope
1984-7	Chairman of Medical Optics Technical Group, OSA.
1984-7	Technical Program Committee, OSA.
1987	SLO Presentation: NIH 100th Anniversary Celebration and at Congress.
1991	Fellow, Optical Society of America
1999	Edwin H. Land Medal, Optical Society of America and the Society for Imaging Science and Technology
2003	Doctor of Science (ScD), honoris causa, SUNY College of Optometry

Part II: Research, Training and Clinical Contributions

A. Narrative Report:

I am an inventor – primarily of diagnostic medical instrumentation. My current specialization is in new forms of confocal microscopy, but I also maintain a continuing involvement with earlier work in ophthalmologic optics and flow cytometry. The essence of invention is the ability to see the fundamentals of a problem and to strip away extraneous additions. Therefore, I am rewarded in many ways for the considerable effort I put into teaching my art. In Physics, review articles and chapters (in *some* journals and books) have more prestige than they do in biomedical disciplines, because seeing a problem from a new direction is a means to extending its reach. As is true in all fields, teaching what I know opens new insights for me, and results in new inventions. The move to MGH has enabled me to broaden my teaching, as well as the more obvious benefits of association with physicians in departments beyond ophthalmology.

I designed the flow system and optics of one of the early flow cytometers, and these are in use throughout much of the field now. I still work a little in the field (which doesn't change much), and have begun to apply the results of my investigation of the new high brightness LEDs.

My first confocal microscope was the scanning laser ophthalmoscope, which I invented and developed in the early 1980s. There are over 300 papers yearly based on use of this instrument, though most have long since stopped citing its origins. However, new variants and applications occur all the time, and I am involved in some of these.

I brought to Wellman lab my confocal microscope for dermatology, that has been generating medical research projects (and papers), primarily in the hands of the physicians. My job is done, there. However, other types of confocal microscope have occupied my time, primarily directed at solving the problem of achieving optical sectioning with a wide field of view (and always in live patients). The angled confocal microscope looks like a good bet for this problem, and is being explored by other researchers now. The spectrally encoded confocal microscope (really a suggestion by a student) is a solution of the problem of how to accomplish confocal microscopy through a catheter. That is a goal long sought in the field, and we have done it! My microlaser microscope has been carried as far, I think, as it can go with current technology. It is being commercialized, but that is premature, in my opinion. Inventions take time – often a long time.

My current research includes use of high brightness light emitting diodes for visual psychophysics displays and new microscopy. I am also collaborating on a scanning laser ophthalmoscope for mice that will use adaptive optics to make retinal cells visible non-invasively. I am designing optics for a group at BU Photonics Center on a diagnostic for Alzheimer's Disease that involves the crystalline lens of the human eye.

History of major research or development projects:

- 1962-9 Nuclear Magnetic Resonance and Electron Spin Resonance evaluation of molecular kinetics. Overhauser and related effects.
- 1970 Arc Spectrophotometer for physiologic Na and K
- 1971 Tonometer - the 'pneumotonometer' sold variously by Alcon and Digilab. This and AO's 'puff' were the two major stand-alone tonometers for many years.
- 1973 Micro-Raman spectrometer - this is the original μ Raman built for NBS (Hirschfeld, JOSA 63:476 (1973), Rosasco and Etz, Research/Development 28:20(1977)).
- 1975 Flow cytometer - 'Cytomat', the model for much of current commercially available flow cytometry. (H M Shapiro, *Practical Flow Cytometry*, Liss,(2003)).
- 1978 Scanning laser ophthalmoscope. This and its offshoots have been the focus of most of my work from then to the present.
- 1990 Spatially Resolved Refractometer. This is one of a group of instruments for characterizing the refractive state of the eye.
- 1991 Microlaser Microscope. A totally new, all solid state confocal microscope.
- 1994 Confocal Microscopes for *in vivo* studies - dermatology and ophthalmology.
- 1999 A coaxial version of the Spatially Resolved Refractometer , which is now extensively in use as the InterWave system by clinicians at Emory.
- 2003 High brightness LED illumination for visual psychophysics and microscopy. This has enabled a number of new approaches to instruments in visual psychophysics and low vision aids, as well as microscopes that may play a roll in diagnosing and monitoring treatment of AIDS and TB in the third world.

B Funding Information

SBIR grants (R43 and R44) do not allow the academic partner to be the PI. However, those listed here are **all** based on RH Webb's inventions.

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|----|-----------------------|--------------------------------|--------------------------------|--|
| 1. | 7/1/78 - 3/31/82 | R01 EY02521
\$473 896 | PI | Fundus visualization and measurement
(The original SLO grant) |
| 2. | 4/1/82 - 3/31/85 | R01 EY03966
\$358 604 | PI, yr 1
Co Inv
yrs 2 &3 | Low vision reading: Optimizing visuo-
motor performance. |
| 3. | 1/1/83 - 12/31/84 | CooperVision
\$500 000 | PI | SLO Development |
| 4. | 12/1/84 -
11/30/87 | R01 EY05626
\$680 868 | PI | Retinal imaging - scatter and indirect
illumination. |
| 5. | 9/86 | Rodestock
\$2,250,000 | PI | SLO License to G. Rodestock
Instrumente GmbH |
| 6. | 3/1/89 - 2/28/91 | GE Medical
Systems\$112 000 | Co Inv | GE/LASE: Control and diagnostics for
laser surgery of the cornea. |

7.	12/1/89	R43 EY08800 \$49,000	Co Inv	SBIR with OPTRA Real-time Corneal Profiler
8.	1991	R01 RR06914 \$575,791	PI	Microlaser Microscope awarded, then given up in favor of DOE grant
9.	1992-2002	DOE : DE-FG 02-91ER61229 \$3,370,000	PI	DOE Center of Excellence for laser applications in medicine – Microlaser Microscope, Real-time imaging and diagnostics
10.	7/3/91-2/28/95	R43&R44 EY09015 \$534,000 total	Co Inv	SBIR with Fourward Laser Anomaloscope (with S Burns)
11.	89-93	R43&R44 EY08794 \$524,380	Co Inv	SBIR with Schwartz Electro-Optics Tunable Wavelength SLO (with A Elsner)
12.	91-93	R44 EY09506 \$550,000	Co Inv	SBIR with Winchester Digital Systems A digital video camera for low vision aids.
13.	12/1/92	R43 EY09494 \$74,049	Co Inv	SBIR with OPTRA Intra-ocular distance measuring interferometer
14.	1992	R43 EY09775 \$49,966	Co Inv	SBIR with Photonics Research Multiwavelength laser arrays for medical imaging
15.	7/93-1/94	R43 RR07737 \$50,000	Co Inv	SBIR with General Scanning Confocal laser microscope - video, vector and zoom
16.	7/94-1/95	R43 AG43046 \$74,624	Co Inv	SBIR with General Scanning Laser micro-scanner for treatment of microvascular lesions
17.	9/1/94 - 8/31/00	R01 EY10285 \$126,103	Co Inv	Low Vision Reading with Electronic Display PI: Peli.
18.	95-96	R43 EY11040 \$100,000	Co Inv	SBIR with Laser Diagnostic Technologies (with A Elsner).
19.	7/1/97 - 12/31/97	R43 RR12279 \$100,000	Co Inv	SBIR with New Dimension Res., Inc. Confocal scanning micro-laser/detector microscope
20.	7/1/97 - 12/31/97	R43 EY11577 \$99,990	Co Inv	SBIR with Physical Sciences Inc , Stabilized SLO Image
21.	1997-8	R43-GM57108	Co Inv	SBIRs with New Dimension, A portable gene scanner.

		\$100,000		
22.	1/1/97-12/31/99	Lucid, Inc. \$389,520 over five years.	PI	Development of new confocal microscopes for medical diagnostics in patients.
23.	9/1/97 to 8/31/00	RO1 EY04395 \$175,143	Co Inv	Investigation of Human Cone Pigment Kinetics PI: Burns
24.	11/1/97-	R43-EY12067 \$62,050	Co Inv	SBIR with New Dimension, A handheld confocal scanning ophthalmoscope.
25.	1999-2002	Emory Vision Correction Center \$120,000/yr	PI	Spatially Resolved Refractometer
26.	10/1/98-3/31/99	R41 EY12065 \$100,000.	PI	STTR for Tandem Ophthalmoscope, SERI and LUCID.
27.	1998-2000	R44 RR12279 \$800,000	CoInv	SBIR Phase II with New Dimension Res., Inc. Confocal scanning micro- laser/detector microscope
28.	2001-2004	R44 EY11819 \$800,000	Co Inv	Portable line scanning laser ophthalmoscope. This is a simple version of a confocal ophthalmoscope.
29.	2002-2006	R01 EY 14106-01 \$9,860,489	Co Inv	Live microscopy and cytometry in vascular biology This BRP develops new instrumentation and applies it in research into vascular growth and hemodynamics.
30.	2002-2005	R01 EY14165 \$988,500	PI	New technologies for illumination and display in vision research This BRG applies newly developed light sources and modulators for psychophysics.
31.	2002-2007	1R01EY014375 \$1,817,988	Co Inv	Adaptive Optics Instrumentation for Advanced Ophthalmic Imaging In this BRP the goal is to use adaptive optics technology to greatly improve human retinal imaging resolution.

C. Current Research:

Development of new variants on confocal microscopes for use in live patients. This includes the angled confocal microscope and the spectrally encoded confocal microscope, as well as exploration of the reasons we see unstained tissue as well as we do. Two of my laboratory rooms are devoted to these endeavors. (Funded by Lucid, Inc. I am PI.) These projects are my major effort.

Development of a wave front analyzer to direct detailed laser surgery of the cornea. Improvements to the Spatially Resolved Refractometer I invented some time ago, we have built an instrument now in use at Emory University. The work was done in my lab at SERI, and future development during the trial will be done there. (Funded by Emory Vision Correction Center. I am the PI.)

Investigation of Human Cone Pigment Kinetics. This is a project of Steven Burns in which I am involved because we are developing a new way to detect the photoreceptor light return, using variants of the confocal techniques I have developed. The Spatially Resolved Refractometer is also used here (Dr. Burns has mine), and we both work on the new version for Emory. My role here includes data analysis techniques. (Funded by NEI, Steven Burns is the PI.)

Development of diagnostic tools and techniques for confocal microscopy. Because I develop new microscopes, I must perforce develop new techniques for evaluating them. Typical are a fiber optic phantom that looks very promising for confocal microscopy, and a simple method for checking the resolution performance of microscopes. Most of the experimentation here is done by others, I just use the devices I have specified, and am writing them up for publication. Another such project, now complete, was the exploration of the effects of index matching on the spherical aberrations of microscope objective lenses.

D. Teaching:

1962-68 Tufts University, Assistant Professor, Physics. This was a full time teaching position. Two students received their PhDs under my direction, and another received an MS.

Since returning to academia in 1979, I have supervised a number of Post-Docs and junior researchers, who have gone on to be valued colleagues both in my labs here and at other institutions. I have done no formal teaching of courses in recent years. Since I am often asked to give tutorial and invited talks at OSA and elsewhere, I think my personal sense that teaching is a strong component of my work is confirmed by my peers.

Recent supervisees:

Ann Elsner - Junior faculty at SERI (now Associate Scientist there)
Eva Beausancourt - ophthalmologist fellow (now in residency in Munich)
Douglas Wornson - technician trainee (now a principal of Amtech, Inc)

Evan Sherr - Master's student (now at Cynosure)
Milind Rajadhyaksha - Post Doc, now at NorthEastern Univ and Sloan Keettering
Ravi Durvasala - PhD candidate, Tufts
Fran Rogomentich – MS, technician-engineer, now at Draper Labs
Juliet Mervis - PhD candidate, Harvard
Der Shen Wan - Post Doc (from Arizona) now at Veeco
Michael Kempe – Post Doc (from NM) now at Zeiss, Jena
Gary Tearney - Post Doc (from Harvard / HST) now at Wellman Center for Photomedicine
Brett Bouma - Junior faculty at Wellman Laboratories - Associate Prof HMS.
Honzhi Zhao – Post Doc (from Beijing Institute of Technology) now at Clemson.
Juan-Manuel Benavides – MS (UT Austin) LEDs and such. Returned to Peru.
Ahmed Rashed – MS (from Bryn Mawr) on LEDs project
David P Biss – Post Doc (from Rochester) working on AOSLO for mice

PUBLICATIONS:

Book: Webb RH, *Elementary Wave Optics*. New York, Academic Press, 1969:270. Reissued by Dover Publications 2005.

Original Reports:

1. Webb RH, Dynamic polarization anomalies in organic free radicals. *Phys. Rev. Letters* 1961;**6**:611-613.
2. Webb RH, Steady-state nuclear polarizations via electronic transitions. *Am. J. Phys.* 1961;**29**:428-444.
3. Webb RH and Griffiths RB, Crystal rotator for cryostat. *Rev. Sci. Ins.* 1961;**32**:363-364.
4. Webb RH, Use of traveling wave helices in ESR and double resonance spectrometers. *Rev. Sci. Instrum.* 1962; **33**:732-737.
5. Limon PJ and Webb RH, A magnetic resonance experiment for the undergraduate laboratory. *Am. J. Phys.* 1964; **32**:361-364.
6. Walker RF and Webb RH, Direct current klystron filament supply. *Rev. Sci. Instrum.* 1965;**36**:1244.
7. Pearlman MR and Webb RH, Characteristics of traveling wave helices in ESR spectrometers. *Rev. Sci. Instrum.* 1967;**38**:1264-1267.
8. Webb RH, Electron-Spin-Resonance line shape in spherical metal particles. *Phys. Rev.* 1967;**158**:225-233.
9. Webb RH (Guest Editor), Apparatus Notes section. *Am. J. Phys.* 1967;**35**, xxi.
10. Nghia NV, Pearlman MR and Webb RH, Recent results in dynamic polarization studies of liquids. *Chem. Phys. Letters* 1968;**2**:176-178.
11. Poindexter EH, Potenza JA, Thompson DD, Nghia NV and Webb RH, Dynamic polarization in fluorocarbons: Effect of scalar correlation time. *Mol. Phys.* 1968;**14**:385-391.
12. Webb RH, Holography for the sophomore laboratory. *Am. J. Phys.* 1968;**36**:62-63.
13. Webb RH, Nghia NV, Pearlman MR, Poindexter EH, Caplan PJ and Potenza JA, Dynamic nuclear polarization: Collision mechanics in fluorocarbon solutions. *J. Chem. Phys.* 1969;**50**:4408-4417.
14. Curbelo R, Schildkraut ER, Hirschfeld T, Webb RH, Block MJ and Shapiro HM, A generalized machine for automated flow cytology system design. *J. Histochem. Cytochem.* 1976;**24**:388-395.
15. Shapiro HM, Schildkraut ER, Curbelo R, Turner RB, Webb RH, Brown DC and Block MJ, Cytomat-R: A computer-controlled multiple laser source multiparameter flow cytophotometer system. *J. Histochem. Cytochem.* 1977;**25**:836-844.
16. Shapiro HM, Young RE, Webb RH and Wiernik PH, Multi-parameter flow cytometric characterization of cell populations in acute leukemia. *Blood* 1977;**50**:209.
17. Delori FC, Castany MA and Webb RH, Fluorescence characteristics of sodium fluorescein in plasmas and whole blood. 1978;*Exp. Eye Res.* **27**:417-425.

18. Schildkraut ER, Shapiro HM, Hercher M, Young RE, Matsu N, Brown D and Webb RH, A system for storage and retrieval of individual cells following flow cytometry. *J. Histochem. Cytochem.* 1979;**27**:289-292.
19. Pomerantzeff O, Webb RH and Delori FC, Image formation in fundus cameras. *Invest. Ophthalmol. Vis Sci.* 1979;**18**:630-637.
20. Webb RH, Hughes GW and O Pomerantzeff, Flying spot TV ophthalmoscope. *Appl. Optics* 1980;**19**:2991-2997.
21. Webb RH and Hughes GW, Scanning laser ophthalmoscope. *IEEE Trans. Biomed. Eng.* 1981;**28**:488-492.
22. Mainster MA, Timberlake GT, Webb RH and Hughes GW, Scanning laser ophthalmoscopy: Clinical applications. *Ophthalmology* 1982;**89**:852-857.
23. Timberlake GT, Mainster MA, Webb RH, Hughes GW and Trempe CL, Retinal localization of scotomata by scanning laser ophthalmoscopy. *Invest Ophthalmol. Vis Sci.* 1982;**22**:91-97.
24. Webb RH, Optics for laser rasters. *Appl. Optics* 1984;**23**:3680-3.
25. Webb RH. Manipulating laser light for ophthalmology. *IEEE Engineering in Medicine and Biology Magazine* 1985;**4**:12-16.
26. Webb RH, Hughes GW, Delori FC, Confocal scanning laser ophthalmoscope. *Appl. Optics*, 1987;**26**:1492-1499.
27. Wornson DP, Hughes GW and Webb RH, Fundus tracking with the scanning laser ophthalmoscope. *Appl. Optics*, 1987;**26**:1500-1504.
28. Webb RH and Delori FC, How we see the retina. 1988;Reprinted in: *Laser Technology in Ophthalmology*, J. Marshall (ed.), Kugler & Ghedini Pub., pp 3-14.(this was accepted for publication in *Lasers and Light in Ophthalmology*, but deflected to the editor's book without my knowledge. RW).
29. Ormerod LD, Fariza E, Hughes GW, Doane MG, and Webb RH. Anterior segment fluorescein videoangiography with scanning angiographic microscope. *Ophthalmology*, 1990;**97**:745-751.
30. Webb RH, Penney CM, and Thompson KP, Measurement of ocular wavefront distortion with a spatially resolved refractometer. *Applied Optics*, 1992;**31**:3678-3686.
31. Elsner AE, Burns SA, Hughes GW, and Webb RH, Reflectometry with a scanning laser ophthalmoscope, *Applied Optics*, 1992;**31**:3697-3710.
32. Webb RH, Concentrator for laser light. *Applied Optics*, 1992;**31**:5917-5918. ((short) full paper)
33. Elsner AE, Burns SA, and Webb RH, Mapping cone photopigment optical density, *J. Opt. Soc. Amer., A.* 1993;**10**:1-7.
34. Webb RH, Hughes GW, Detectors for video rate scanning images, *Applied Optics*, 1993;**32**: 6227-6235.
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36. Webb RH and Rogomentich FJ, Microlaser microscope using self detection for confocality, *Optics Letters*,1995;**20**,533-535.
37. Rajadhyaksha M and Webb RH, Plate Beam-Splitter to Produce Multiple Equal-Intensity Beams, *Applied Optics* 1995;**34** 8066-8067.

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39. Ormerod LD, Fariza E and Webb RH, Dynamics of external ocular blood flow studied by scanning angiographic microscopy. *Eye*, 1995; **9** 605-614.
40. Webb RH Confocal Optical Microscopy. *Reports on Progress in Physics* 1996; **59** 427-471. This includes both teaching on confocal microscopy and review of various approaches, as well as new material.
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44. Webb,RH, Theoretical Basis of Confocal Microscopy, *Methods in Enzymology* **307**: 3-20 (1999).
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57. Benavides, JM and RH Webb, "Optical characterization of ultrabright LEDs" *Applied Optics* **44** 4000-4003 (2005).
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Patents: (U.S. Patent numbers only)

1. Young NO and Webb RH, Liquid sample spectral source. 1971; **3,609,041**.
2. Webb RH, Applanation tonometer comprising porous air bearing support for applanating piston. 1973; **3,714,819**.
3. Webb RH, Mosaic photoelectric target. 1975; **3,894,259**.
4. Pomerantzeff O and Webb RH, Scanning ophthalmoscope for examining the fundus of the eye. 1980; **4,213,678**.
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6. Webb RH, Double scanning optical apparatus and method. 1988; **4,765,730**.
7. Webb RH, Double scanning optical apparatus and method. 1988; **4,768,873**.
8. Webb RH and Wornson DP, Scanning optical apparatus and method. 1988; **4,768,874**.
9. Webb RH, Optical scanning system and method including correction for cross scan error. 1990; **4,893,920**.
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11. Penney CM, Thompson KP, and Webb RH, Objective eye alignment measurement method and system. 1993; **5,214,455**.
12. Penney CM, Webb RH, Tiemann JT and Thompson KP, Spatially resolved objective autorefractometer. 1993; **5,258,791**.
13. Webb RH, Concentrator for laser light 1994; **5,309,339**.
14. Webb RH and Rogomentich FJ, Laser Imaging System Using Self-detection for Confocality 1996; **5,563,710**.
15. Feke GT, Delori FC and Webb RH, Beam Steering Optical System and Ophthalmic Apparatus Using Same 1997; **5,633,695**.
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17. Webb RH Scanning ophthalmoscope with spatial light modulators. 1999; **5,867,251**.
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19. Webb RH Confocal scanning microscope with angled objective lenses for improved axial resolution. **5,973,828** (1999).
20. Anderson RR, Webb RH and Rajadhyaksha M, Three-dimensional scanning confocal laser microscope. **5,995,283** (1999).
21. Webb RH, Burns SA and Penney, CM, Coaxial spatially resolved refractometer **6,000,800** (1999).
22. Webb RH Scanning ophthalmoscope with spatial light modulators. **6,003,993** (2000).
23. Webb RH, Burns SA and Penney, CM, Coaxial spatially resolved refractometer **6,099,125** (2000).
24. Webb RH Confocal scanning microscope with angled objective lenses for improved axial resolution. **6,118,580** (2000).
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26. Hang, Z, Lazarev, V, and Webb, RH Optical confocal device having a common light directing means. **6,121,603** (2000).
27. Elsner, AE, Webb RH, and Dreher, A, Apparatus for near simultaneous observation of directly scattered image field and multiply scattered image field. **6,236,877** (2001).
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29. Burns, SA and Webb, RH Method and apparatus for measurement and correction of optical aberration **6,486,943** (2002).
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31. Lin, CP and Webb, RH Fiber-coupled multiplexed confocal microscope **6,747,795** (2004).
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Invited Papers, Book Chapters and Conference Reports:

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