Curriculum Vitae Albert Polman

Prof.dr. Albert Polman
Director and Scientific Group Leader
FOM Institute for Atomic and Molecular Physics (AMOLF)
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Personal details
Date of birth: April 21, 1961
Place of birth: Groningen, The Netherlands
Nationality: Dutch

Scientific education

1989	PhD Thesis: *Beam-induced phase transformations in silicon* (University of Utrecht, advisors: F.W. Saris and W.C. Sinke)
1985	MSc Physics, University of Utrecht (The Netherlands)
1981	BSc Physics, University of Utrecht (The Netherlands)

Past positions

2006-present	Director and Scientific Group Leader, FOM Institute AMOLF, Amsterdam. *AMOLF is one of the research laboratories of the Foundation for Fundamental Research on Matter (FOM), the physics division of the Dutch National Science Foundation. With a yearly budget of 15 million euro, AMOLF employs about 150 research staff and 50 support staff.*
2005	Head, Center for Nanophotonics, FOM Institute AMOLF
2003-2004	Visiting associate, California Institute of Technology, USA (*sabbatical leave*)
1999-2004	Department Head, FOM Institute AMOLF
1996-present	Professor of Nanophotonics, University of Utrecht
1991-present	Scientific group leader, FOM Institute AMOLF
1989-1991	Post-doctoral staff researcher, AT&T Bell Laboratories (Murray Hill, NJ, USA)
1985-1989	PhD researcher, FOM Institute AMOLF

Distinctions and awards

2009	Member, Royal Dutch Academy of Sciences (KNAW)
2008	Honorary Member, International Committee of the Ion Beam Modification of Materials (IBMM) conference series
2007	Member, Royal Dutch Society of Sciences (Koninklijke Hollandse Maatschappij der Wetenschappen)

Publications, citations, presentations and patents

Publications	> 200 publications in refereed international journals
Citations	> 8000 citations; > 1000 citations in 2009; Hirsch index: 50
Presentations	> 80 invited presentations at international conferences, several of which as plenary or keynote speaker.
Patents	4 patents granted, 1 patent application pending

Memberships/program directorships

2010-present	Member, Executive Board National Nanoinitiative "*High tech systems and materials*" (125 M€ national research program),
2009-present	Program manager, FOM Program *Nanophotovoltaics*

2004-present	Member, Steering Committee FOM-Philips Industrial Partnership Program *Microphotonic Light Sources*
2004-present	Member, Program Committee FOM-Shell Industrial Partnership Program *Third generation solar cells*
2004-present	Member, Advisory Board of the Centre of Excellence for Advanced Silicon Photovoltaics and Photonics of the University of New South Wales (Australia)
2004-present	Member, Scientific Advisory Board, Leibnitz Research Center Rossendorf (Germany)
2004-present	Member, International Advisory Board of the University of Surrey Ion Beam Centre (United Kingdom)
2002-present	Program manager, Flagship *Nanophotonics*, Dutch Nanotechnology Program NANONED
2005-2008	Chair/Member, Nanophysics and technology Advisory Board of FOM
2004-2005	Member, Board of Directors of the Materials Research Society (Pittsburgh)
2000-2006	Member, Advisory Board of the Photonics Research Institute COBRA of the Technical University Eindhoven.
1999-2008	Program manager, National FOM research program *Photon Physics in Optical Materials*
1998-2008	Secretary/Member, International Committee, Ion Beam Modification of Materials Conference

Editorships of journals and proceedings

2007-present	Member, Editorial Advisory Board of NanoLetters (Americal Chemical Society)
2000-present	Member, Advisory Editorial Board of Physica B (Elsevier)
2000	Volume Organizer (co-editor), MRS Bulletin

Conference Organisation

2006	Chairman, First Gordon Research Conference *Plasmonics - optics at the nanoscale* (Keene, USA)
2004	Co-chair, Symposium *Nanophotonic materials*, European Materials Research Society Meeting (Strasbourg)
2003	Co-chair, MRS Spring Meeting (San Francisco, USA, > 3000 attendees)
1998	Chairman, 11th International Conference on Ion Beam Modification of Materials (Amsterdam, 350 attendees)
1997	Co-organiser, Symposium *Materials and devices for Si based opto-electronics*, MRS Spring Meeting (San Francisco, 1997)
1996	Co-organiser, Symposium *Rare earth doped semiconductors II*, MRS Spring Meeting (San Francisco, 1996)
1994	Co-organiser, Symposium *Film synthesis and growth using energetic beams*, MRS Fall Meeting (Boston, 1994)

Industrial collaborations (many leading to joint publications or patents)

2005-present	Philips Research: microphotonic light sources, plasmonics, soft nano-imprinting
2005-present	Shell Research: plasmonic photovoltaics
2005-present	FEI Company: plasmonics, focussed ion beam nanofabrication
1999-2001	Symmorphix: optical doping, planar optical amplifiers
1996-2000	AKZO-Nobel: polymer optical amplifiers
1995-2002	ST Microelectronics: Si-based light sources:
1991-1994	PTT/KPN: optical doping, planar optical amplifiers
1989-1991	AT&T Bell Laboratories: optical doping, integrated optics

Top-ten publications in the last 10 years

1. *A single-layer wide-angle negative index metamaterial at visible frequencies*, S. Burgos, R. de Waele, A. Polman, and H,A. Atwater, Nature Materials **9**, in press (2010)
2. *A silicon-based electrical source of surface plasmon polaritons*, R.J. Walters, R.V.A. van Loon, I. Brunets, J. Schmitz and A. Polman, Nature Materials **9**, 21 (2010) (with News and Views article)
3. *Plasmonics for improved photovoltaic devices*, H.A. Atwater and A. Polman, Nature Materials **9**, 205 (2010) (with Editorial article)
4. *Nanowire plasmon excitation by adiabatic mode transformation*, E. Verhagen, M. Spasenović, A. Polman, and L. Kuipers, Phys. Rev. Lett. **102**, 203904 (2009)
5. *Purcell factor enhanced scattering from Si nanocrystals in an optical microcavity*, T. J. Kippenberg, A. L. Tchebotareva, J. Kalkman, A. Polman, and K. J. Vahala, Phys. Rev. Lett. **103**, 027406 (2009)
6. *Plasmonic solar cells,* K.R. Catchpole and A. Polman, Optics Express **16**, 21793 (2008)
7. *Plasmon slot waveguides: towards chip-scale propagation with subwavelength-scale localization,* J.A. Dionne, L. Sweatlock, H.A. Atwater, and A. Polman, Phys. Rev. B **73**, 035407 (2006)
8. *Polarization-selective plasmon-enhanced Si quantum dot luminescence,* H. Mertens, J.S. Biteen, H.A. Atwater, and A. Polman, Nano Lett. **6**, 2622 (2006)
9. *Highly confined electromagnetic fields in arrays of strongly coupled Ag nanoparticles,* L.A. Sweatlock, S.A. Maier, H.A. Atwater, J.J. Penninkhof, and A. Polman, Phys. Rev. B **71**, 235408 (2005)
10. *Strong exciton-erbium coupling in Si nanocrystal-doped SiO_2 ,* P.G. Kik, M.L. Brongersma, and A. Polman, Appl. Phys. Lett. **76**, 2325 (2000)

Other recent papers of expected impact

1. *Are negative index materials achievable with surface plasmon waveguides? A case study of three plasmonic geometries*, J.A. Dionne, E. Verhagen, A. Polman, and H.A. Atwater, Optics Express **16**, 19001 (2008), also highlighted in Nature Mater. **7**, 925 (2008)
2. *Tunable nanoscale localization of energy on plasmon particle arrays,* R. de Waele, A.F. Koenderink, and A. Polman, Nano Lett. **7**, 2004 (2007), also highlighted in Nature **448**, 141 (2007)
3. *Direct imaging of propagation and damping of near-resonance surface plasmon polaritons using cathodoluminescence spectroscopy,* J.T. van Wijngaarden, E. Verhagen, A. Polman, C.E. Ross, H.J. Lezec, and H.A. Atwater, Appl. Phys. Lett. **88**, 221111 (2006), also highlighted in Science **312**, 1719 (2006)
4. *Improved red-response in thin film a-Si:H solar cells with soft-imprinted plasmonic back reflectors,* V.E. Ferry, M.A. Verschuuren, H.B.T. Li, R.E.I. Schropp, H.A. Atwater, and A. Polman, Appl. Phys. Lett. **95**, 183503 (2009)

5 most highly cited articles:

1. *Erbium implanted thin film photonic materials*, A. Polman, J. Appl. Phys. **82**, 1 (1997) **(647 citations)**
2. *Defect-related versus excitonic visible light emission from ion beam synthesized Si nanocrystals in SiO_2,* K.S. Min, K.V. Shcheglov, C.M.Yang, H.A. Atwater, M.L. Brongersma and A. Polman, Appl. Phys. Lett. **69**, 2033 (1996) **(318 citations)**
3. *Room-temperature electroluminescence from Er-doped crystalline Si*, G. Franzo, F. Priolo, S. Coffa, A. Polman, and A. Carnera, Appl. Phys. Lett. **64**, 2235 (1994) **(280 citations)**
4. *Temperature dependence and quenching processes of the intra-4f luminescence of Er in crystalline Si*, S. Coffa, G. France, F. Priolo, A. Polman, and R. Serna, Phys. Rev. B. **49**, 16313 (1994) **(208 citations)**
5. *Strong exciton-erbium coupling in Si nanocrystal-doped SiO_2,* P.G. Kik, M.L. Brongersma and A. Polman, Appl. Phys. Lett. **76**, 2325 (2000) **(183 citations)**

Review articles

1. *Broadband sensitizers for erbium-doped planar optical amplifiers: review*, A. Polman and F.C.J.M. van Veggel. J. Opt. Soc. Am. B. **21**, 871 (2004)
2. *Rare earth doped polymers for planar optical amplifiers (review article)*, L.H. Slooff, A. Polman, S.I. Klink, L. Grave, F.C.J.M. van Veggel and J.W. Hofstraat, J. Appl. Phys. **91**, 3955 (2002)
3. *Erbium as a probe of everything? (review article)*, A. Polman, Physica B **300**, 78 (2001)

Opinion articles

1. *Plasmonics applied*, A. Polman, Science **322**, 868 (2008)
2. *Photonic Materials - Teaching silicon new tricks,* A. Polman, Nature Materials **1**, 10 (2002)

Plenary/keynote presentations

1. *Plasmonics: optics at the nanoscale (plenary),* Euromat, Glasgow, September 7-10, 2009
2. *Plasmonics: optics at the nanoscale (plenary),* CLEO/QELS Conference, May 6-9, 2008, San Jose, CA
3. *Plasmonic photovoltaics* (*keynote*), SPIE Europe, Brussels, April 12-16, 2010
4. *Plasmonics: optics at the nanoscale (keynote),* QELS-CLEO Europe, June 16-19, 2009, Munich
5. *The plasmonic Purcell effect (keynote),* SPIE Conference, San Diego, August 2-6, 2009

Scientific Leadership Profile

Content and impact of the major scientific or scholarly contributions

Albert Polman is one of the world's leading scientists in nanophotonics, the research area concerned with the control, understanding, and application of light at the nanoscale. After his seminal invention of optical doping using ion beams, Polman developed a research program on nanoscale optics ranging from studies on optical doping to light emission from silicon, spontaneous emission control, silicon quantum dots, rare-earth doped organics, and most recently, nanophotonics using surface plasmons. Over the past 20 years, Polman's group has been leading in all these research directions.

Following his PhD research on laser- and ion-beam induced phase transformations in silicon, Polman was appointed as a post-doctoral researcher at the prestigious AT&T Bell Laboratories (NJ, USA). Here, he invented the concept of **optical doping**: the incorporation and optical activation of optically active rare earth ions in thin-film materials by ion implantation. Polman pioneered this technique and was among the first to carry out optical spectroscopy in optical waveguides. His miniature planar optical amplifier was later commercialized.

Subsequently, Polman changed focus and became a pioneer of **optical doping** of semiconductors and the study of **optical interactions** in these materials. With collaborators in Catania he identified the energy transfer mechanism between the intra-4*f* states of the rare earth ions and exciton traps in Si. Many research groups worldwide have followed Polman on this topic since then.

Subsequently, Polman started experiments on modifying the dielectric environment around optical emitters using the optical doping technique. In collaboration with Sandia National Laboratories Polman was the first to demonstrate **modified spontaneous emission** in a three-dimensional photonic crystal with a full photonic bandgap. In subsequent work, he demonstrated that Förster energy transfer is not affected by the local density of states in the optical spectral range. Most recently, Polman and co-workers at Caltech revealed that **scattering in a high-Q optical microcavity** occurs preferentially into high-Q waveguide modes and is described by the Purcell factor that also describes cavity-enhanced spontaneous emission.

As a sidetrack along his optical experiments, Polman studied **ion-solid interactions**. His ion implantation expertise enabled him to fabricate unique optical materials or structures that are otherwise impossible to make. Polman's work revealed, on a microscopic scale, the effects of radiation-induced Newtonian viscous flow, anisotropic deformation, and point defect generation and annihilation during ion irradiation of silica glass. He was the first to relate macroscopic parameters to microscopic phenomena that occur in the picosecond thermal spike of the nanoscale ion track. He also identified the role of capillary forces in shape changes of nanoscale objects under ion irradiation.

Achieving light emission from silicon nanostructures is one of the holy grails of opto-electronic technology, and Polman's group has played a key role in establishing this research field worldwide. Together with Caltech, Polman pioneered a novel way to fabricate **optically active Si quantum dots** in a SiO_2 matrix; their two key papers are very highly cited. Polman was the first to demonstrate energy transfer between quantum confined excitonic states in Si nanostructures and the 4*f* electronic shells of the rare earth ions bringing together the fields of optical doping and quantum confined exciton emission in Si, which lead to a very active research field on this topic.

In the past five years, Polman has redirected his group's research activities towards **plasmonics**, the manipulation of light using metallic nanostructures. His group:
- developed a near-field optical microscopy imaging technique to study the propagation, damping and dispersion of surface plasmon polaritons at length scales well below the diffraction limit;
- pioneered the use of cathodoluminescence imaging spectroscopy as a technique to study the dispersion and local density of states of surface plasmon polaritons at nanoscale resolution;
- fabricated nanoparticle plasmonics waveguides demonstrating frequency-tuneable localization of light;
- studied the coupling between plasmonic nanoparticles and optical emitters such as Si quantum dots and Er ions, and demonstrated strongly enhanced and polarization-controlled photo- and electroluminescence;
- developed a molecular templating technique using DNA to assemble plasmonic nanostructures with unique (bio-)sensing properties;
- demonstrated the first Si-compatible electrical source of surface plasmon polaritons.

Most recently, Polman has expanded his activities into the area of **plasmonic photovoltaics**. He has developed the fundamental design rules for plasmon enhanced photocurrent collection from solar cells, enabling the design and fabrication of an entirely new class of ultra-thin solar cells.

Ability to productively change research fields & establish new interdisciplinary approaches

As is clear from the above, Polman has regularly changed research topic over the past years, initiating new research themes. Every time, in starting new research topics he took advantage of knowledge and techniques developed in previous work. For all of these new topics he proved to be a leader. The quality of Polman's most recent work in plasmonics is exemplified by the fact that he has published three articles in the prestigious journal *Nature Materials* in the past half year.

International recognition and diffusion

Polman is acknowledged worldwide as the pioneer of the optical doping technique; his review article on his work has been cited over 600 times. His work on Er-doped Si, together with the Catania group, lead to the most highly cited papers in this field. Similarly, his work on Si quantum dots lead to the most highly cited papers in that research field. In the ion beam community, he was an invited speaker at every bi-annual IBMM conference for 10

years. He is also one of the leaders of the plasmonics field as testified by several interviews and opinion articles published in Nature and Science. He has given over 80 invited talks at international conferences, several of which as plenary or keynote speaker.

Polman has organized several conferences in his field. He chaired various symposia at MRS conferences, chaired the IBMM conference in 1998, and was co-chair of the MRS Spring Meeting in 2003. In 2006 initiated a new Gordon Conference series on plasmonics. Polman is member of many advisory boards and committees and was appointed member of the Royal Netherlands Academy of Sciences in 2009. He has authored over 200 articles accumulating over 8000 citations with a H-index of 50.

In the Netherlands, Polman initiated several national research programmes and facilities: the programme *Photon Physics in Optical Materials* of the Dutch Foundation for Fundamental Research on Matter (FOM), the NanoNED Flagship Nanophotonics, and the Amsterdam nanoCenter cleanroom, a national nanofabrication facility for nanophotonics. In 2005 he established the Centre for Nanophotonics at the FOM- AMOLF, a research centre with over 40 nanophotonics scientists.

In recognition of his scientific leadership, Polman was appointed director of the FOM Institute AMOLF in 2006, while remaining active as a scientific group leader. With a yearly budget of 15 million euro, AMOLF employs about 150 research staff and 50 support staff. Under his guidance, the institute underwent an international panel evaluation in 2006, at which the institute as a whole and each of its research programmes were rated as excellent. Most recently, Polman successfully steered the institute into a direction where high-quality fundamental research is combined with effective initiatives to achieve knowledge transfer to industry and society.

Efforts and ability to inspire younger researchers

Polman is associated with the University of Utrecht as a professor of nanophotonics since 1996, and has taught a full-semester course since then every year, first on thin-film materials analysis, and since 2005 on nanophotonics. All Polmans's master and PhD students working at AMOLF have graduated from Utrecht University.

Master students: Polman developed a new teaching method for his materials science class, in which lectures are composed of 6 "lecture clips" of 15 min each, corresponding to the typical student's attention span. Polman presented the method first at an MRS symposium in 1997 and then published it in the Journal of Materials Education. It has served as an example to many other teachers. The students' ratings for Polman's courses are consistently between 8 and 9 (on a 1 to 10 scale).

PhD students and postdocs: Polman supervised to date 16 PhD students and 11 postdocs. They have gone on to leading positions such as professorships at Stanford University, Florida State University and Leiden University, and staff positions at various institutions, including:

- *Universities:* U.C. Santa Barbara, Institute of Optics Madrid, UFRGS Brazil, Groningen University, Australian National University, University of Aix-Marseille
- *Government research labs:* ECN, KAIST Korea, Fraunhofer Institute, RIVM, CNRS, AMOLF
- *Industry:* Shell, ST Microelectronics, Genexis, Philips Research, NXP, dBVision