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Surface plasmon lasers

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Bibliography

- [1] G. G. Stokes, in *Rep. 16th Meet. Brit. Assoc. Adv. Sci.* (Murray, London, Southampton, 1846), pp. 1–20.
- [2] Walter Munk, Frank Snodgrass, and George Carrier, *Edge Waves on the Continental Shelf*, *Science* **123**, 127 (1956).
- [3] M. Fleischmann, P. J. Hendra, and A. J. McQuillan, *Raman spectra of pyridine adsorbed at a silver electrode*, *Chemical Physics Letters* **26**, 163 (1974).
- [4] E. C. Le Ru, E. Blackie, M. Meyer, and P. G. Etchegoin, *Surface Enhanced Raman Scattering Enhancement Factors: A Comprehensive Study*, *The Journal of Physical Chemistry C* **111**, 13794 (2007).
- [5] F. J. Garcia-Vidal, L. Martín-Moreno, and J. B. Pendry, *Surfaces with holes in them: new plasmonic metamaterials*, *Journal of Optics A: Pure and Applied Optics* **7**, S97 (2005).
- [6] Nina Meinzer, William L. Barnes, and Ian R. Hooper, *Plasmonic meta-atoms and metasurfaces*, *Nature Photonics* **8**, 889 (2014).
- [7] R. A. Shelby, D. R. Smith, and S. Schultz, *Experimental Verification of a Negative Index of Refraction*, *Science* **292**, 77 (2001).
- [8] D. R. Smith, J. B. Pendry, and M. C. K. Wiltshire, *Metamaterials and Negative Refractive Index*, *Science* **305**, 788 (2004).
- [9] Wenshan Cai and Vladimir Shalaev, *Optical Metamaterials* (Springer, New York, NY, 2010).
- [10] Zhaowei Liu, Hyesog Lee, Yi Xiong, Cheng Sun, and Xiang Zhang, *Far-Field Optical Hyperlens Magnifying Sub-Diffraction-Limited Objects*, *Science* **315**, 1686 (2007).
- [11] J. B. Pendry, *Negative Refraction Makes a Perfect Lens*, *Physical Review Letters* **85**, 3966 (2000).
- [12] Fu Min Huang, Tsung Sheng Kao, Vassili A. Fedotov, Yifang Chen, and Nikolay I. Zheludev, *Nanohole Array as a Lens*, *Nano Letters* **8**, 2469 (2008).

- [13] Francesco Aieta, Patrice Genevet, Mikhail A. Kats, Nanfang Yu, Romain Blanchard, Zeno Gaburro, and Federico Capasso, *Aberration-Free Ultrathin Flat Lenses and Axicons at Telecom Wavelengths Based on Plasmonic Metasurfaces*, Nano Letters **12**, 4932 (2012).
- [14] Yang Zhao and Andrea Alù, *Manipulating light polarization with ultrathin plasmonic metasurfaces*, Physical Review B **84**, 205428 (2011).
- [15] Nanfang Yu, Francesco Aieta, Patrice Genevet, Mikhail A. Kats, Zeno Gaburro, and Federico Capasso, *A Broadband, Background-Free Quarter-Wave Plate Based on Plasmonic Metasurfaces*, Nano Letters **12**, 6328 (2012).
- [16] Carl Pfeiffer, Cheng Zhang, Vishva Ray, L. Jay Guo, and Anthony Grbic, *High Performance Bianisotropic Metasurfaces: Asymmetric Transmission of Light*, Physical Review Letters **113**, 023902 (2014).
- [17] Xingjie Ni, Zi Jing Wong, Michael Mrejen, Yuan Wang, and Xiang Zhang, *An ultrathin invisibility skin cloak for visible light*, Science **349**, 1310 (2015).
- [18] Thomas W. Ebbesen, H. J. Lezec, H. F. Ghaemi, T. Thio, and P. A. Wolff, *Extraordinary optical transmission through sub-wavelength hole arrays*, Nature **391**, 667 (1998).
- [19] Frerik van Beijnum, Peter J. van Veldhoven, Erik Jan Geluk, Gert W. 't Hooft, and Martin P. van Exter, *Loss compensation of extraordinary optical transmission*, Applied Physics Letters **104**, 061112 (2014).
- [20] Frerik van Beijnum, Peter J. van Veldhoven, Erik Jan Geluk, Michiel J. A. de Dood, Gert W. 't Hooft, and Martin P. van Exter, *Surface Plasmon Lasing Observed in Metal Hole Arrays*, Physical Review Letters **110**, 206802 (2013).
- [21] M. A. Noginov, G. Zhu, A. M. Belgrave, R. Bakker, V. M. Shalaev, E. E. Narimanov, S. Stout, E. Herz, T. Suteewong, and U. Wiesner, *Demonstration of a spaser-based nanolaser*, Nature **460**, 1110 (2009).
- [22] Martin T. Hill, Yok-Siang Oei, Barry Smalbrugge, Youcai Zhu, Tjibbe de Vries, Peter J. van Veldhoven, Frank W. M. van Otten, Tom J. Eijkemans, Jaroslaw P. Turkiewicz, Huug de Waardt, Erik J. Geluk, Soon-Hong Kwon, Yong-Hee Lee, Richard Notzel, and Meint K. Smit, *Lasing in metallic-coated nanocavities*, Nature Photonics **1**, 589 (2007).
- [23] Rupert F. Oulton, Volker J. Sorger, Thomas Zentgraf, Ren-Min Ma, Christopher Gladden, Lun Dai, Guy Bartal, and Xiang Zhang, *Plasmon lasers at deep subwavelength scale*, Nature **461**, 629 (2009).

-
- [24] Ren-Min Ma, Rupert F. Oulton, Volker J. Sorger, Guy Bartal, and Xiang Zhang, *Room-temperature sub-diffraction-limited plasmon laser by total internal reflection*, *Nature Materials* **10**, 110 (2011).
- [25] Xiangeng Meng, Jingjing Liu, Alexander V. Kildishev, and Vladimir M. Shalaev, *Highly directional spaser array for the red wavelength region*, *Laser & Photonics Reviews* **8**, 896 (2014).
- [26] J. Stehr, J. Crewett, F. Schindler, R. Sperling, G. von Plessen, U. Lemmer, J.M. Lupton, T.A. Klar, J. Feldmann, A.W. Holleitner, M. Forster, and U. Scherf, *A Low Threshold Polymer Laser Based on Metallic Nanoparticle Gratings*, *Advanced Materials* **15**, 1726 (2003).
- [27] Jae Yong Suh, Chul Hoon Kim, Wei Zhou, Mark D. Huntington, Dick T. Co, Michael R. Wasielewski, and Teri W. Odom, *Plasmonic Bowtie Nanolaser Arrays*, *Nano Letters* **12**, 5769 (2012).
- [28] Wei Zhou, Montacer Dridi, Jae Yong Suh, Chul Hoon Kim, Dick T. Co, Michael R. Wasielewski, George C. Schatz, and Teri W. Odom, *Lasing action in strongly coupled plasmonic nanocavity arrays*, *Nature Nanotechnology* **8**, 506 (2013).
- [29] A. Hinke Schokker, *Periodic and Aperiodic Plasmon Lattice Lasers*, Ph.D. thesis, University of Amsterdam, Amsterdam, 2016.
- [30] Mohammad Ramezani, Alexei Halpin, Antonio I. Fernández-Domínguez, Johannes Feist, Said Rahimzadeh-Kalaleh Rodriguez, Francisco J. Garcia-Vidal, and Jaime Gómez Rivas, *Plasmon-exciton-polariton lasing*, *Optica* **4**, 31 (2017).
- [31] Hua Zhang, L. Andrea Dunbar, Giacomo Scalari, Romuald Houdré, and Jérôme Faist, *Terahertz photonic crystal quantum cascade lasers*, *Optics Express* **15**, 16818 (2007).
- [32] Y. Chassagneux, R. Colombelli, W. Maineult, S. Barbieri, H. E. Beere, D. A. Ritchie, S. P. Khanna, E. H. Linfield, and A. G. Davies, *Electrically pumped photonic-crystal terahertz lasers controlled by boundary conditions*, *Nature* **457**, 174 (2009).
- [33] J. B. Pendry, L. Martín-Moreno, and F. J. Garcia-Vidal, *Mimicking Surface Plasmons with Structured Surfaces*, *Science* **305**, 847 (2004).
- [34] Kazuaki Sakoda, *Optical Properties of Photonic Crystals* (Springer, Berlin, 2005).

- [35] H. Kogelnik and C. V. Shank, *Coupled-Wave Theory of Distributed Feedback Lasers*, Journal of Applied Physics **43**, 2327 (1972).
- [36] Kazuyoshi Hirose, Yong Liang, Yoshitaka Kurosaka, Akiyoshi Watanabe, Takahiro Sugiyama, and Susumu Noda, *Watt-class high-power, high-beam-quality photonic-crystal lasers*, Nature Photonics **8**, 406 (2014).
- [37] M. P. van Exter, V. T. Tenner, F. van Beijnum, M. J. A. de Dood, P. J. van Veldhoven, E. J. Geluk, and G. W. 't Hooft, *Surface plasmon dispersion in metal hole array lasers*, Optics Express **21**, 27422 (2013).
- [38] Pierre Berini and Israel De Leon, *Surface plasmon-polariton amplifiers and lasers*, Nature Photonics **6**, 16 (2012).
- [39] Min W. Kim and P.-C. Ku, *Semiconductor nanoring lasers*, Applied Physics Letters **98**, 201105 (2011).
- [40] Israel De Leon and Pierre Berini, *Amplification of long-range surface plasmons by a dipolar gain medium*, Nature Photonics **4**, 382 (2010).
- [41] W. L. Barnes, W. A. Murray, J. Dintinger, E. Devaux, and T. W. Ebbesen, *Surface Plasmon Polaritons and Their Role in the Enhanced Transmission of Light through Periodic Arrays of Subwavelength Holes in a Metal Film*, Physical Review Letters **92**, 107401 (2004).
- [42] P Lalanne, *A microscopic view of the electromagnetic properties of sub- λ metallic surfaces*, Surface Science Reports **64**, 453 (2009).
- [43] F. J. Garcia-Vidal, L. Martin-Moreno, T. W. Ebbesen, and L. Kuipers, *Light passing through subwavelength apertures*, Reviews of Modern Physics **82**, 729 (2010).
- [44] Frerik van Beijnum, Chris R  tif, Chris B. Smiet, Haitao Liu, Philippe Lalanne, and Martin P. van Exter, *Quasi-cylindrical wave contribution in experiments on extraordinary optical transmission*, Nature **492**, 411 (2012).
- [45] Raffaele Colombelli, Kartik Srinivasan, Mariano Troccoli, Oskar Painter, Claire F. Gmachl, Donald M. Tennant, A. Michael Sergent, Deborah L. Sivco, Alfred Y. Cho, and Federico Capasso, *Quantum Cascade Surface-Emitting Photonic Crystal Laser*, Science **302**, 1374 (2003).
- [46] W. L. Barnes, *Fluorescence near interfaces: The role of photonic mode density*, Journal of Modern Optics **45**, 661 (1998).
- [47] ioffe, Semiconductor database of the Ioffe physical technical institute, St. Petersburg, Russia. <http://www.ioffe.rssi.ru/SVA/NSM/Semicond/>.

-
- [48] P. Paddon and Jeff F. Young, *Two-dimensional vector-coupled-mode theory for textured planar waveguides*, Physical Review B **61**, 2090 (2000).
- [49] D. M. Whittaker and I. S. Culshaw, *Scattering-matrix treatment of patterned multilayer photonic structures*, Physical Review B **60**, 2610 (1999).
- [50] N. Rotenberg, M. Spasenović, T. L. Krijger, B. le Feber, F. J. García de Abajo, and L. Kuipers, *Plasmon Scattering from Single Subwavelength Holes*, Physical Review Letters **108**, 127402 (2012).
- [51] C. Ropers, D. Park, G. Stibenz, G. Steinmeyer, J. Kim, D. Kim, and C. Lienau, *Femtosecond Light Transmission and Subradiant Damping in Plasmonic Crystals*, Physical Review Letters **94**, (2005).
- [52] V. T. Tenner, A. N. van Delft, M. J. A. de Dood, and M. P. van Exter, *Loss and scattering of surface plasmon polaritons on optically-pumped hole arrays*, Journal of Optics **16**, 114019 (2014).
- [53] Alexandre G. Brolo, Reuven Gordon, Brian Leathem, and Karen L. Kavanagh, *Surface Plasmon Sensor Based on the Enhanced Light Transmission through Arrays of Nanoholes in Gold Films*, Langmuir **20**, 4813 (2004).
- [54] Ahmet A. Yanik, Min Huang, Osami Kamohara, Alp Artar, Thomas W. Geisbert, John H. Connor, and Hatice Altug, *An Optofluidic Nanoplasmonic Biosensor for Direct Detection of Live Viruses from Biological Media*, Nano Lett. **10**, 4962 (2010).
- [55] H. Ditlbacher, J. R. Krenn, G. Schider, A. Leitner, and F. R. Aussenegg, *Two-dimensional optics with surface plasmon polaritons*, Applied Physics Letters **81**, 1762 (2002).
- [56] A. Melikyan, L. Alloatti, A. Muslija, D. Hillerkuss, P. C. Schindler, J. Li, R. Palmer, D. Korn, S. Muehlbrandt, D. Van Thourhout, B. Chen, R. Dinu, M. Sommer, C. Koos, M. Kohl, W. Freude, and J. Leuthold, *High-speed plasmonic phase modulators*, Nature Photonics **8**, 229 (2014).
- [57] William L. Barnes, Alain Dereux, and Thomas W. Ebbesen, *Surface plasmon subwavelength optics*, Nature **424**, 824 (2003).
- [58] Ren-Min Ma, Rupert F. Oulton, Volker J. Sorger, and Xiang Zhang, *Plasmon lasers: coherent light source at molecular scales: Plasmon lasers: coherent light source at molecular scales*, Laser & Photonics Reviews **7**, 1 (2013).
- [59] H. Gao, J. M. McMahon, M. H. Lee, J. Henzie, S. K. Gray, G. C. Schatz, and T. W. Odom, *Rayleigh anomaly-surface plasmon polariton resonances*

- in palladium and gold subwavelength hole arrays*, Optics Express **17**, 2334 (2009).
- [60] I. Vurgaftman, J. R. Meyer, and L. R. Ram-Mohan, *Band parameters for III–V compound semiconductors and their alloys*, Journal of Applied Physics **89**, 5815 (2001).
 - [61] K Petermann, *Laser diode modulation and noise* (Kluwer Academic Publishers ; KTK Scientific Publishers ; Sold and distributed in the U.S.A. and Canada by Kluwer Academic Publishers, Dordrecht; Boston; Tokyo; Norwell, MA, 1988).
 - [62] Sheng S Li, *Semiconductor physical electronics* (Plenum, New York, 1993).
 - [63] B. Tromborg, H.E. Lassen, and H. Olesen, *Traveling wave analysis of semiconductor lasers: modulation responses, mode stability and quantum mechanical treatment of noise spectra*, IEEE Journal of Quantum Electronics **30**, 939 (1994).
 - [64] F van Beijnum, A.S. Meeussen, C. Rétif, and M.P van Exter, *Rayleigh scattering of surface plasmons by sub-wavelength holes*, Optics Express **22**, 10317 (2014).
 - [65] V. T. Tenner, M. J. A. de Dood, and M. P. van Exter, *Measurement of the Phase and Intensity Profile of Surface Plasmon Laser Emission*, ACS Photonics **3**, 942 (2016).
 - [66] R. W. Gerchberg and W. O. Saxton, *Practical Algorithm for Determination of Phase from Image and Diffraction Plane Pictures*, Optik **35**, 237 (1972).
 - [67] James R. Fienup, *Phase retrieval algorithms: a personal tour [Invited]*, Applied optics **52**, 45 (2013).
 - [68] J. M. Rodenburg and H. M L Faulkner, *A phase retrieval algorithm for shifting illumination*, Applied Physics Letters **85**, 4795 (2004).
 - [69] K. Sakai, E. Miyai, T. Sakaguchi, D. Ohnishi, T. Okano, and S. Noda, *Lasing band-edge identification for a surface-emitting photonic crystal laser*, IEEE Journal on Selected Areas in Communications **23**, 1335 (2005).
 - [70] Eiji Miyai, Kyosuke Sakai, Takayuki Okano, Wataru Kunishi, Dai Ohnishi, and Susumu Noda, *Photonics: Lasers producing tailored beams*, Nature **441**, 946 (2006).
 - [71] M. Notomi, H. Suzuki, and T. Tamamura, *Directional lasing oscillation of two-dimensional organic photonic crystal lasers at several photonic band gaps*, Applied Physics Letters **78**, 1325 (2001).

-
- [72] Masahiro Imada, Alongkarn Chutinan, Susumu Noda, and Masamitsu Mochizuki, *Multidirectionally distributed feedback photonic crystal lasers*, Physical Review B **65**, (2002).
- [73] Yan Cui, Ravi S. Hegde, In Yee Phang, Hiang Kwee Lee, and Xing Yi Ling, *Encoding molecular information in plasmonic nanostructures for anti-counterfeiting applications*, Nanoscale **6**, 282 (2014).
- [74] Na Liu, Martin Mesch, Thomas Weiss, Mario Hentschel, and Harald Giessen, *Infrared Perfect Absorber and Its Application As Plasmonic Sensor*, Nano Letters **10**, 2342 (2010).
- [75] C. Haffner, W. Heni, Y. Fedoryshyn, J. Niegemann, A. Melikyan, D. L. Elder, B. Baeuerle, Y. Salamin, A. Josten, U. Koch, C. Hoessbacher, F. Ducry, L. Juchli, A. Emboras, D. Hillerkuss, M. Kohl, L. R. Dalton, C. Hafner, and J. Leuthold, *All-plasmonic Mach-Zehnder modulator enabling optical high-speed communication at the microscale*, Nature Photonics **9**, 525 (2015).
- [76] O. Hess, J. B. Pendry, S. A. Maier, R. F. Oulton, J. M. Hamm, and K. L. Tsakmakidis, *Active nanoplasmonic metamaterials*, Nature Materials **11**, 573 (2012).
- [77] Jeremy Baumberg, Mikhail Noginov, Javier Aizpurua, Kaiqiang Lin, Thomas Ebbesen, Alexei A Kornyshev, Riccardo Sapienza, Niek van Hulst, Santhosh Kotni, F. Javier García de Abajo, Pavel Ginzburg, Ortwin Hess, Mark Brongersma, and Sergey Bozhevolnyi, *Quantum plasmonics, gain and spasers: general discussion*, Faraday Discuss. **178**, 325 (2015).
- [78] John D. Joannopoulos, Steven G. Johnson, Joshua N. Winn, and Robert D. Meade, *Photonic Crystals: Molding the Flow of Light (Second Edition)* (Princeton University Press, Princeton, 2011).
- [79] W. Streifer, R.D. Burnham, and D.R. Scifres, *Radiation losses in distributed feedback lasers and longitudinal mode selection*, IEEE Journal of Quantum Electronics **12**, 737 (1976).
- [80] Y. Chassagneux, R. Colombelli, W. Maineult, S. Barbieri, S. P. Khanna, E. H. Linfield, and A. G. Davies, *Graded photonic crystal terahertz quantum cascade lasers*, Applied Physics Letters **96**, 031104 (2010).
- [81] Gangyi Xu, Raffaele Colombelli, Suraj P. Khanna, Ali Belarouci, Xavier Letartre, Lianhe Li, Edmund H. Linfield, A. Giles Davies, Harvey E. Beere, and David A. Ritchie, *Efficient power extraction in surface-emitting semiconductor lasers using graded photonic heterostructures*, Nature Communications **3**, 952 (2012).

- [82] Geert Morthier and Patrick Vankwikelberge, *Handbook of Distributed Feedback Laser Diodes, Second Edition* (Artech House, Boston, 2013).
- [83] Martin T. Hill, *Status and prospects for metallic and plasmonic nano-lasers [Invited]*, J. Opt. Soc. Am. B **27**, B36 (2010).
- [84] Kyosuke Sakai, Eiji Miyai, and Susumu Noda, *Two-dimensional coupled wave theory for square-lattice photonic-crystal lasers with TM-polarization*, Optics express **15**, 3981 (2007).
- [85] K. Sakai, E. Miyai, and S. Noda, *Coupled-Wave Theory for Square-Lattice Photonic Crystal Lasers With TE Polarization*, IEEE Journal of Quantum Electronics **46**, 788 (2010).
- [86] I. Vurgaftman and J.R. Meyer, *Design optimization for high-brightness surface-emitting photonic-crystal distributed-feedback lasers*, IEEE Journal of Quantum Electronics **39**, 689 (2003).
- [87] Rudolf F. Kazarinov and Charles H. Henry, *Second-order distributed feedback lasers with mode selection provided by first-order radiation losses*, Quantum Electronics, IEEE Journal of **21**, 144 (1985).
- [88] C. Ferreira Fernandes, *Mode spectrum and threshold gain calculations in DFB lasers*, Microwave and Optical Technology Letters **12**, 363 (1996).
- [89] Toshihiko Makino and Jan Glineski, *Transfer matrix analysis of the amplified spontaneous emission of DFB semiconductor laser amplifiers*, Quantum Electronics, IEEE Journal of **24**, 1507 (1988).
- [90] P. Vankwikelberge, G. Morthier, and R. Baets, *CLADISS-a longitudinal multi-mode model for the analysis of the static, dynamic, and stochastic behavior of diode lasers with distributed feedback*, IEEE Journal of Quantum Electronics **26**, 1728 (1990).
- [91] Joseph W. Goodman, *Introduction To Fourier Optics* (Roberts and Company Publishers, Englewood, Colorado, 2005).
- [92] L. J. Allen and M. P. Oxley, *Phase retrieval from series of images obtained by defocus variation*, Optics communications **199**, 65 (2001).
- [93] Alon Greenbaum and Aydogan Ozcan, *Maskless imaging of dense samples using pixel super-resolution based multi-height lensfree on-chip microscopy*, Optics Express **20**, 3129 (2012).
- [94] S. Marchesini, *A unified evaluation of iterative projection algorithms for phase retrieval*, Review of Scientific Instruments **78**, 011301 (2007).

-
- [95] V. T. Tenner, M. J. A. de Dood, and M. P. van Exter, *Surface plasmon dispersion in hexagonal, honeycomb and kagome plasmonic crystals*, Optics Express **24**, 29624 (2016).
- [96] J. B. Pendry, D. Schurig, and D. R. Smith, *Controlling Electromagnetic Fields*, Science **312**, 1780 (2006).
- [97] Justyna K. Gansel, Michael Thiel, Michael S. Rill, Manuel Decker, Klaus Bade, Volker Saile, Georg von Freymann, Stefan Linden, and Martin Wegener, *Gold Helix Photonic Metamaterial as Broadband Circular Polarizer*, Science **325**, 1513 (2009).
- [98] Hikaru Saito and Naoki Yamamoto, *Size dependence of bandgaps in a two-dimensional plasmonic crystal with a hexagonal lattice*, Optics Express **23**, 2524 (2015).
- [99] W. L. Barnes, T. W. Preist, S. C. Kitson, and J. R. Sambles, *Physical origin of photonic energy gaps in the propagation of surface plasmons on gratings*, Physical Review B **54**, 6227 (1996).
- [100] Jean-Luc R. Stevens, Philipp Rudiger, and James A. Bednar, in *HoloViews: Building Complex Visualizations Easily for Reproducible Science* (<http://conference.scipy.org>, Austin, 2015), pp. 61–69.
- [101] Sadao Adachi and John Wiley & Sons, *Physical properties of III-V semiconductor compounds InP, InAs, GaAs, GaP, InGaAs, and InGaAsP* (Wiley, New York, 1992).
- [102] Takayuki Okamoto and Satoshi Kawata, *Dispersion relation and radiation properties of plasmonic crystals with triangular lattices*, Optics Express **20**, 5168 (2012).
- [103] M. Kerker, D.-S. Wang, and C. L. Giles, *Electromagnetic scattering by magnetic spheres*, Journal of the Optical Society of America **73**, 765 (1983).
- [104] Haitao Liu and Philippe Lalanne, *Microscopic theory of the extraordinary optical transmission*, Nature **452**, 728 (2008).
- [105] Haitao Liu and Philippe Lalanne, *General properties of the surface charge pattern of one-dimensional metallic gratings*, Optics Express **21**, 16753 (2013).
- [106] Xin Zhang, Haitao Liu, and Ying Zhong, *Microscopic analysis of surface Bloch modes on periodically perforated metallic surfaces and their relation to extraordinary optical transmission*, Physical Review B **89**, 195431 (2014).

- [107] D. V. Coevorden, *Light propagation in Ordered and Disordered Media*, Ph.D. thesis, Universiteit van Amsterdam, 1997.
- [108] Shanhui Fan and J. D. Joannopoulos, *Analysis of guided resonances in photonic crystal slabs*, Physical Review B **65**, 235112 (2002).
- [109] Virginie Lousse, Wonjoo Suh, Onur Kilic, Sora Kim, Olav Solgaard, and Shanhui Fan, *Angular and polarization properties of a photonic crystal slab mirror*, Optics Express **12**, 1575 (2004).
- [110] Simon Bernard, Christoph Reinhardt, Vincent Dumont, Yves-Alain Peter, and Jack C. Sankey, *Precision resonance tuning and design of SiN photonic crystal reflectors*, Optics Letters **41**, 5624 (2016).
- [111] Wonjoo Suh, M. F. Yanik, Olav Solgaard, and Shanhui Fan, *Displacement-sensitive photonic crystal structures based on guided resonance in photonic crystal slabs*, Applied Physics Letters **82**, 1999 (2003).
- [112] Chong Pei Ho, Prakash Pitchappa, Piotr Kropelnicki, Jian Wang, Hong Cai, Yuandong Gu, and Chengkuo Lee, *Two-dimensional photonic-crystal-based Fabry–Perot etalon*, Optics Letters **40**, 2743 (2015).
- [113] Masahiro Imada, Susumu Noda, Alongkarn Chutinan, Takashi Tokuda, Michio Murata, and Goro Sasaki, *Coherent two-dimensional lasing action in surface-emitting laser with triangular-lattice photonic crystal structure*, Applied Physics Letters **75**, 316 (1999).
- [114] M. Meier, A. Mekis, A. Dodabalapur, A. Timko, R. E. Slusher, J. D. Joannopoulos, and O. Nalamasu, *Laser action from two-dimensional distributed feedback in photonic crystals*, Applied Physics Letters **74**, 7 (1999).
- [115] Y. Chassagneux, R. Colombelli, W. Maineult, S. Barbieri, S. P. Khanna, E. H. Linfield, and A. G. Davies, *Predictable surface emission patterns in terahertz photonic-crystal quantum cascade lasers*, Optics Express **17**, 9491 (2009).
- [116] K. J. Moh, X.-C. Yuan, J. Bu, R. E. Burge, and Bruce Z. Gao, *Generating radial or azimuthal polarization by axial sampling of circularly polarized vortex beams*, Applied Optics **46**, 7544 (2007).
- [117] Yu Tokizane, Kazuhiko Oka, and Ryuji Morita, *Supercontinuum optical vortex pulse generation without spatial or topological-charge dispersion*, Optics Express **17**, 14517 (2009).
- [118] Ignacio Moreno, Jeffrey A. Davis, Isaac Ruiz, and Don M. Cottrell, *Decomposition of radially and azimuthally polarized beams using a circular-polarization and vortex-sensing diffraction grating*, Optics Express **18**, 7173 (2010).

- [119] Kyoko Kitamura, Kyosuke Sakai, Naoki Takayama, Masaya Nishimoto, and Susumu Noda, *Focusing properties of vector vortex beams emitted by photonic-crystal lasers*, Optics Letters **37**, 2421 (2012).
- [120] Gerard Nienhuis, *Analogies between optical and quantum mechanical angular momentum*, Philosophical Transactions of the Royal Society A **375**, 20150443 (2017).
- [121] Felix Bloch, *Über die Quantenmechanik der Elektronen in Kristallgittern*, Zeitschrift für Physik **52**, 555 (1929).
- [122] Léon Brillouin, *Les électrons dans les métaux et le classement des ondes de de Broglie correspondantes*, Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences **191**, 292 (1930).
- [123] A. E. Siegman, *Lasers* (University Science Books, Stanford, 1986).
- [124] Yong Liang, Chao Peng, Kenji Ishizaki, Seita Iwahashi, Kyosuke Sakai, Yoshinori Tanaka, Kyoko Kitamura, and Susumu Noda, *Three-dimensional coupled-wave analysis for triangular-lattice photonic-crystal surface-emitting lasers with transverse-electric polarization*, Optics Express **21**, 565 (2013).

Curriculum Vitae

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- 2001-2007 High school degree VWO (NT and NG profile), Lorentz Casimir Lyceum, Eindhoven
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Teaching assistant for experimental physics and for atomic and molecular physics.

List of publications

- M. P. van Exter, V. T. Tenner, F. van Beijnum, M. J. A. de Dood, P. J. van Veldhoven, E. J. Geluk, and G. W. 't Hooft, *Surface plasmon dispersion in metal hole array lasers*, Optics Express **21**, 27422 (2013).
- S. Witte, V. T. Tenner, D. W. E. Noom, and K. S. E. Eikema, *Lensless diffractive imaging with ultra-broadband table-top sources: from infrared to extreme-ultraviolet wavelengths*, Light: Science & Applications **3**, e163 (2014).
- V. T. Tenner, A. N. van Delft, M. J. A. de Dood, and M. P. van Exter, *Loss and scattering of surface plasmon polaritons on optically-pumped hole arrays*, Journal of Optics **16**, 114019 (2014).
- V. T. Tenner, K. S. E. Eikema, and S. Witte, *Fourier transform holography with extended references using a coherent ultra-broadband light source*, Optics Express **22**, 25397 (2014).
- V. T. Tenner, M. J. A. de Dood, and M. P. van Exter, *Measurement of the Phase and Intensity Profile of Surface Plasmon Laser Emission*, ACS Photonics **3**, 942 (2016).
- V. T. Tenner, M. J. A. de Dood, and M. P. van Exter, *Surface plasmon dispersion in hexagonal, honeycomb and kagome plasmonic crystals*, Optics Express **24**, 29624 (2016).

