Editorial

Vladimir M. Shalaev*, Jennifer Dionne and Alexandra Boltasseva*

A tribute to Mark Stockman

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Known to many as a pioneer in the field of the ultra-small, Mark Stockman (Professor of Physics at Georgia State University and founding director of the Center for Nano-Optics at Georgia State University) leaves behind a scientific community deprived of a brilliant and outspoken scholar, an inspirational colleague and to many a friend.

When in 2003, Mark Stockman and David J Bergman invented the concept of the Surface Plasmon Amplification by Stimulated Emission of Radiation (SPASER), a nanoplasmonic counterpart of the laser, this discovery significantly shaped the field of nanophotonics and plasmonics. Mark's later theoretical work on active plasmonics and the nano-confinement of light led to other key concepts such as the development of the plasmonic taper and the ultrafast valleytronics that are now widely known in nanophotonics and nanotechnology.

Besides his remarkable scientific discoveries, Mark Stockman was also known for his passionate and deep scientific insights. His detailed knowledge of fundamental science and his passion were presented as a recognizable voice as he frequently challenged scientific concepts at conference presentations, seminars when he was invited to visit institutes and to collaborate with his colleagues and at numerous dinners with colleagues and friends.

To honor Prof. Mark Stockman as a pioneer in the field of Nanophotonics and to celebrate his life, this tribute issue is dedicated to him and his achievements. Below we collected memories of his friends and colleagues with personal anecdotes and pictures in *Shared Memories with Mark* and combined this with their scientific papers.

Guest Editors:

Alexandra Boltasseva
Jennifer Dionne
Vlad Shalaev

Shared Memories with Mark

Andrea Alu
City University of New York, USA

Prof. Mark Stockman has truly been a pioneer and seminal contributor to the broad field of plasmonics and nano-optics – one of the best-known scientists worldwide in our field. He has inspired generations of scientists, and his papers on the spaser, nanofocusing, and various plasmonic nanodevices and functionalities, have been, and continue to be, a must-read for anyone interested in the field of nanoscale light-matter interactions. He was recognized for his deep knowledge of fundamentals and his exceptional intuition.

His profound contributions to science however have not been limited to his scientific discoveries. Since I started my research career, Prof. Stockman has been a continuous and very inspiring presence at conferences and scientific meetings. His questions from the first row on many of the talks he attended have been an important part of my growth as a scientist and educator. With his vision and ideas and with his inquisitive mind and provocative questions he has been truly steering the

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Jennifer Dionne, School of Engineering, Stanford University, Stanford, USA

field, and his impact will continue for decades to come. We will certainly miss Prof. Stockman's presence, but he continues to be with us with his legacy of ideas and inspiration for the next generations of scientists and researchers.

David Bergman
Tel Aviv University, Israel

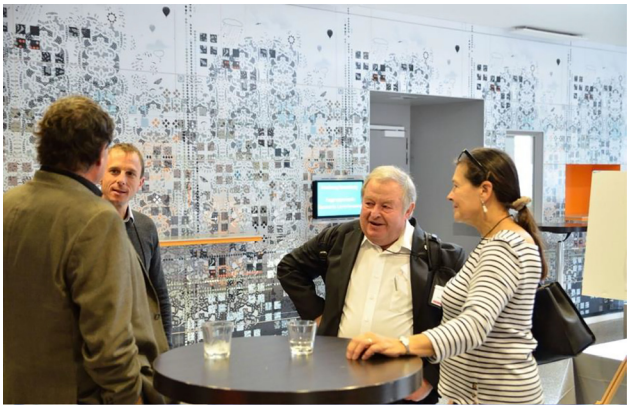
I first met Mark Stockman in the year 2000, when he was already a professor at Georgia State University in Atlanta, GA. Soon afterward, we started to collaborate on the plasmonic properties of thin metal films and other nanometric media. In 2003, we proposed the idea of "surface plasmon amplification by stimulated emission of radiation". The basic idea was mine, but Mark did most of the related calculations. He also coined the acronym SPASER, which is now used to describe such devices. These have since been realized by various groups. During the years 2001–2005, we co-authored 13 research articles and obtained one patent. Mark was always a very original scientist, and very aggressive in his opinions. I shall always remember the many years of fruitful collaboration with him.

Meeting Mark Stockman from 1999 to 2019

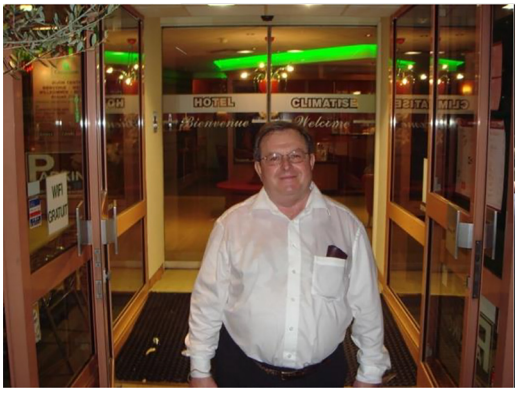
Sergey I. Bozhevolnyi
University of Southern Denmark

The time goes so incredibly fast! Searching my memory for my first personal encounter with Mark Stockman, I have found with a great surprise that it had happened back in 1999, i.e., in the previous millennium! He invited me to stop by and give a seminar at the Physics Department of Georgia State University on the way to my first invited lecture at the OSA Annual Meeting in Santa Clara. He invited me because of my experimental near-field investigations of local field enhancements, "hot" spots, in random and fractal structures, a subject that he pioneered as a theoretician already in 80s back in the Soviet Union. In terms of funding, we were both rather poor at that time (although not exactly as church mice), so he invited me to stay in his house. This was where I met for the first time his kindhearted and charmingly hospitable wife Slava and gentle son Dima. Of course, I still remember his profound comments and advice to look, for example, for statistics in local field enhancements, but frankly speaking, delicious cutlets prepared by Slava are what I most vividly recall!

So many "firsts" back in 1999 led, through 20 years of many interesting discussions at various meetings and conferences, to our last encounter at The Plasmonics conference, SPP9, held in Copenhagen in 2019, that I was honored to chair. This conference was organized and set up by Asger Mortensen and myself, and there was no way, whatsoever (!), that we would not invite Mark Stockman to come and make it shine – we did and, fortunately, he agreed and did make it shine! There was already written so much about the importance of Mark's participation in any conference, his great influence, and his inspirational questions – he alone could make a memorable event out of any meeting, even an obscure one. So, let me just share these photos made during SPP9, the 10th conference on plasmonics, at which Mark left his unique mark of encyclopedic knowledge, uncompromising scrutiny, as well as contagious interest and inspiring attitude to new physics.



Boris N. Chichkov
Leibniz Universität Hannover, Germany



Jen Dionne
Stanford University

It is hard to believe that Mark is no longer with us. Mark was such an inspiring member of our community and a terrific role model. He approached each problem with thoughtfulness, vigor, creativity, and joy. I met Mark as a graduate student (at the first plasmonics Gordon conference pictured below, in 2006), and he played a key role in shaping the scientist I became. He was always full of terrific questions, usually from the front row of any conference – from San Diego to Seefeld. Yet beyond his scientific rigor, Mark exuded a love of life and adventure. I know his spirit will live on in each of us, and we will forever celebrate his life, inspiration, and legacy!

Nader Engheta

University of Pennsylvania, USA

I first met Mark at a conference in Richardson, Texas in January 2004. Although I had been familiar with some of his papers before then, this was the first time I met Mark in person. He was very kind to me, and we became friends immediately. Our friendship grew over time. I always enjoyed discussing scientific topics with Mark, and I always learned from him. An inspirational pioneer and an influential scientific leader, he was always the lively spirit of any scientific meeting he attended. He was a scientific giant and a towering figure in various fields of light-matter interaction. It is hard to imagine future plasmonics and photonics conferences without Mark. He loved life and he lived it to the fullest. He will be missed, but his scientific vision, technical contributions and pioneering ideas will live forever.


DON'T NEED
Therapy
I JUST NEED TO GO TO
AUSTRALIA

Maria Farsari
Foundation for Research and Technology – Hellas/Institute of Electronic Structure & Laser (IESL), Greece

I find it very hard to think of Mark as not being with us anymore. He was not part of my everyday life, but a point-of-reference in many of my travels. He was a beautiful mind that loved science and books of all kinds. Also, he was a lot of fun. He loved telling stories holding a glass of good red wine. We met in many places: Seefeld, Singapore, Munich, Changchun, San Diego, San Francisco. My fondest memory of him is in San Francisco when, after dinner, he insisted I shouldn't walk back to the hotel by myself. It was raining heavily, and he got so wet that the hotel porter brought him towels to dry himself.

Mark loved his family most of all. He would always talk about his Slava and Dmitry and, even though he loved traveling, he would always try to spend as much time as possible at home. Their life, and everyone's that knew him, is emptier without him.

So long, Mark, and thank you for the memories.

My favorite photograph of Mark. Singapore, July 2009. Photograph by Daniel S. Pickard.

Always on a lookout

Jacob Khurgin
Johns Hopkins University, Whiting School of Engineering, USA

If I could come up with one picture that would reveal in full Mark's outsized personality, it would be a picture of him sitting at the very center of the front row of any Conference or workshop he attended. In the case of the conference on nanophotonics in San Diego that he himself organized for many years, he would be sitting by himself at the desk placed in front of the rest of the audience. One could think of him as a bus or a locomotive driver, or a pilot charting the path for the lumbering ships behind him. Never tired. Always alert. Always on the lookout. Always ready for the unpredictable. And ready he always was – the moment the talk would finish Mark's hand would go up, and in his very methodic way, never raising his voice, he would start taking the talk apart. Anyone (and there have been great many of us) who had ever been on the receiving end of his soliloquy fretted over these encounters, but in the end, the truth always won and the critique that was given by Mark always ended up as constructive contribution. And the second picture of Mark that has been engraved in my memory is having a boisterous discourse with him over a few beers, especially Après Ski, not just about

science but about many other aspects of life and society. And there was a different Mark – warm, funny, emotional, just as the best friends are. And for me, those two pictures summarize it all. I just hope that the front chair will not remain empty forever.

Yuri Kivshar
Australian National University, Australia

I met Mark Stockman at one of the conferences; he approached me after my talk and introduced himself. He somehow knew that I am from Kharkov, the city where he was born in 1947. I was very proud to learn about one more great scientist from Kharkov. Although Mark did not belong to the famous Kharkov School of Theoretical Physics established by Lev Landau well before we both were born, he absorbed the great energy and inspiring environment of this city, and that time expanding Jewish community of outstanding scientists.

I did communicate with Mark many times after moving to the field of nanophotonics. We had long debates about our study of nonlinear nanofocusing in tapered plasmonic waveguides published in 2010 (A. Davoyan et al., Phys. Rev. Lett. **105**, 116804 [2010]) where we suggested using tapered waveguides for enhancing nonlinear effects at the nanoscale. Mark told me that he liked that work after all, as well as our other paper on Airy plasmons (A. Minovich et al., Phys. Rev. Lett. **107**, 116802 [2011]).

We spent with Mark one week together in Roma in 2008, attending a very stimulating and relaxing small workshop organized by Concita Sibilia. Mark found the great restaurant "Le Tavernelle" (Via Panisperna, 48, 00184 Roma), and he was really excited by taking all of us there to absorb the spirit of great science. Indeed, from the foundation of the restaurant in 1870, many people visited Le Tavernelle. Most remarkably, this was the place often visited by Fermi, Segrè, Pontecorvo, and others, known as the Boys of Via Panisperna, all featured on the restaurant walls. Mark selected that table to be as close as possible to the genius.

My friends call Mark "evangelist of plasmonics" for his great inspiration and many creative ideas he brought to this field. I fully agree with them, but Mark will also be remembered for his great and open personality. And I hope one day he will be recognized in Kharkov as one of its greatest sons.

Peter Hommelhoff
Department of Physics, FAU Erlangen-Nuernberg, Erlangen, Germany
Matthias Kling and Ferenc Krausz
Department of Physics, LMU Munich, and Max Planck Institute of Quantum Optics, Garching, Germany

Mark Stockman was a pioneer in plasmonics and ultrafast nanoscience. He was also our close collaborator, mentor, dear friend, and skiing partner, and leaves behind a large legacy. Our paths have been strongly intertwined since he paid his first visit to the Max Planck Institute of Quantum Optics (MPQ) in Garching, Germany, in 2007, where in deep discussions about nanoplasmonics and attosecond physics the foundations for attosecond nanophysics were laid. His sense for big

discoveries led him to his path-breaking theory results on strong-field interactions in two-dimensional materials, to ultrafast valleytronics and petahertz optoelectronics, to just name a few of his most recent research foci.

For us, his open-minded and joyful character was equally important as his brilliant mind, which made every encounter with him special. His wit, his broad range of interests, and his outspoken wisdom culminated in one of the most interesting personalities. Mark was a passionate and formidable skier. He often took his skiing gear with him when visiting Europe in winter. Despite a considerable age difference, it was hard to keep up with him. When us filming him skiing down the hill (movies he posted on his website) and arriving a bit out of breath at the bottom of the trail, he calmly stood there and his only question was "So, which trail should we do next?". During his visits in summer, he enjoined rides on his MPQ guest bike, especially along the beautiful Isar river connecting the cities of Garching and Munich.

Mark was an entertaining colleague to have dinner with. Next to the many excellent science discussions we had, we will not forget the various stories he told us with great empathy and joy. He spoke with the highest regard of the United States, giving him and his wife Slava a chance to start a new life when they came with nothing. It was surprising how knowledgeable he was in various fields. He could tell exciting stories about many countries and his preferred food and drinks there, but also, coming from a military family background, on their special forces, for example. At a workshop in Dresden, we jointly went to the Albertinum Museum, where Mark was in this mixed state of mind between being tired because of jet lag and interested attentiveness – only to visit the famous Karl May Bar after a museum visit and conference dinner, where he generously paid drinks for everyone joining.

Mark has formed, mentored, and influenced many people in the most positive sense, namely, to enjoy science *and* life. It has been a true pleasure and wonderful privilege to be close friends with Mark Stockman. We will not forget him.

Renmin Ma

Peking University, Beijing, China

In 2007, I was very lucky to join the team led by Prof. Xiang Zhang to develop nanowire plasmonic nanolasers (spasers). And from then on, my research got entangled with spasers. In September 2011, Mark visited UC Berkeley, we discussed the research on spasers and enjoyed oyster and wine in downtown Berkeley. In July 2019, Mark visited Beijing. Together with Prof. Cun-Zheng Ning, we had a mini-symposium to celebrate ten-year anniversary of spaser experimental demonstration. During the visit, Mark also gave a seminar in my group, and shared the story about how he and Prof. David Bergman developed the key idea of spaser during a conference. Of course, we also enjoyed Chinese food in Beijing. Thank you, Mark, for your encouragements and inspirations.

Asger Mortensen
DKU, Denmark

When I think about Mark, I am always reminded of a particular situation during one of his visits to Denmark. We are seated around the table in the DTU Faculty Club, waiting for the dinner to be served, when one of us is suddenly concerned if Mark would have any issues with the pork (which is an extremely common serving in Denmark). To everybody's relief, Mark then with a big smile tells the story about the kosher pig (which I am sure that many of you know …) ''Every pig has one kosher leg – the challenge is to figure out which one is kosher!''

Cun-Zheng Ning
Arizona State University, USA
Tsinghua University, China

On a lighter and more humorous note, one of our last interactions involved reimbursement of his flight ticket for that last trip to China via wiring the money to his US account. After a few rounds of emails with an accountant, who insisted that he must use his real name, Mark was frustrated and forwarded me their emails, attaching the image of the instructions in Chinese. The instructions in Chinese state that the recipient must be a real person and the name cannot be a "bank", "stock", or "security". I immediately realized the problem, resulting in the following email exchange: Me: Mark, I found out what was wrong. It is hilarious! You have the wrong family name that contains "Stock". Mark: Gosh, you are right! It is hilarious! Please explain to them that I am not traded on stock markets yet as of now.

Let us hope that, with our collective efforts, one day a company making spasers WILL be traded on stock markets!

Mark Stockman and I were having a conversation during our last meeting at Tsinghua University on July 12, 2019.

Mikhail Noginov
Norfolk State University, USA

I remember Mark presenting the concept of a spaser at the Conference On Lasers and Electrooptics (CLEO) conference in Baltimore. It was clearly something revolutionary, but the audience did not swallow it easily.

I remember a hurricane, probably Sandy. It tore New York City but was mild in Virginia Beach, where I live. I got a call from Mark: "Take your family and come to stay with us". Atlanta (where Mark lived) is 10 h away from us (by car), the hurricane was mild, and the evacuation was impractical and unnecessary. However, receiving this invitation was so touching. This is how I will remember Mark.

I also remember a family man, loving and safeguarding his family.

I remember a man, who knew everything about everything, including culture, history, food, and health.

And I also remember the man who loved life so much. Title slides of his multiple presentations showed Mark on skis, expertly negotiating a slope. The winds blowing over Seefeld and Snowbird still remember Mark, and I wish one of the slopes to be named after him.

Lukas Novotny
ETH Zürich, Switzerland

I remember many joint dinners and conversations with Mark. He was an incredibly kind man and a 'bag of knowledge'. I learned a lot from discussions with Mark. He was the person to talk to for a 'sanity proof' of any crazy idea. And by having a drink with him you learned who he really is.. a very special person!

Extreme creativity. Ahead of his time. Life to the full.

Teri Odom

Northwestern University in Evanston, Illinois, USA

When I think about Mark Stockman and his enduring influence on nanophotonics, those three phrases come to mind. Mark was interested in manipulating and squeezing light using exceptionally small structures. Many of his ideas were conceived before experimental set-ups and nanostructure designs were even possible. And when they finally were, his unconventional ideas were validated, manyfold over.

Mark was not afraid of controversy – or for getting to the heart of the matter. I admit that when I first encountered what I'll call the "Stockman focus," I wasn't initially sure how to respond. After my talk was finished, and Mark stood up requesting the microphone to amplify his words, I didn't know: Was he asking me a question that he wished me to respond to? Or was he simply making a statement regarding the results? Over the years, we had many focused discussions that I believe were helpful to me and others. And more often than not, we agreed. My research group has been the beneficiary of Mark's SPASER concept, and I know that to have contributed to its story and realization made Mark proud.

Peace to Mark as his legacy goes on, and on.

Alexander Popov

Birck Nanotechnology Center, Purdue University (retired)

Mark's interest in photonics was formed under the guidance of Professor Sergei Rautian, whose teacher (Grigory Landsberg) was a famous scientist in the field of optical physics. When Rautian moved to the Novosibirsk Scientific Center (Siberia) to establish the Department of Nonlinear Laser Spectroscopy, he recruited Mark as a talent fascinated by the new physics opened by the unique properties of laser light.

From 1975 to 1989, Mark's research led to disruptive results in various fields of photonics. He proposed the selective cutting of DNA, through resonant two-photon absorption by the attached dye molecules, and its applications for genetic engineering and creation of vaccines. He also extended the unique methods of light-induced gas kinetics discovered in the department to produce the flux of electrons in solids directed opposite to the laser beam.

It was also at this institute that Mark began his work on nonlinear plasmonics where giant nonlinearities were revealed. Plasmonics became his main research field further in the US.

When I moved from Rautian's department to establish the Department of Coherent Nonlinear Optics in the Krasnoyarsk Scientific Center (Eastern Siberia), I encouraged members of my department to maintain collaboration with Rautian's team. Among them was my former PHD student Vlad Shalaev who began collaboration with Mark Stockman.

In 1989, I chaired the International School on Lasers and Applications, where Vlad Shalaev chaired the local organizing committee. The sessions were held next to the mountain ski facilities near Sayanogorsk, Khakasia, which is located a few hundred miles from the geometrical center of Asia. Mark's enthusiasm impressed Professor Thomas George, a participant of the school. When Tom told me about a temporary vacancy in his team, I recommended Mark to him. This led to the beginning of Mark's stellar career in the US.

It was February 2019, when I last met Mark. We spent a long and warm night talking at the Ben Gurion Airport after a conference in Ein Gedi had ended. When Vlad messaged me about the incurable illness of Mark, I was shocked, and then had e-mail conversations with Mark almost until his last day while he was in the hospital. He considered his life exciting, meaningful, and complete.

Bitter words of farewell to Mark were posted on the website of his alma mater the Novosibirsk Institute of Automation and Electrometry of the Russian Academy of Sciences.

We will miss Mark.

Mark in 1975, the photo posted on the website of his alma mater institute.

Mark and the co-chairs of a session, Professor Thomas George (right) and Professor Jean-Claude Diels.

Mark, Vlad, and Professor B. Smirnov (Lebedev Institute).

Tigran Shahbazyan
Jackson State University, USA

I befriended Mark during the conference on Cooperative Phenomena in Optics and Transport in Nanostructures, which we (Rudolf Roemer, Mikhail Portnoi, and I) organized at MPIKS, Dresden, in June of 2004. At that time, Mark was not yet a "celebrity", as his paper on *spaser* with David Bergman (who also attended that conference) was published just recently and was not widely known. Mark later told me that this was, in fact, his first invited talk on *spaser* presented at a major conference (see conference photo: Mark is standing in the front row with me to his left).

Over the years, we talked about many things – science, politics, arts, personal issues, etc. Mark had an outgoing personality, and so he freely shared his thoughts and opinions with his numerous friends. Most striking to me, however, was his ability to share other person's suffering (in Russian – "sostradanie"). An example of it I witnessed during the SPIE Optics and Photonics Conference in San Diego, where Mark chaired the plasmonics symposium for many years. As we were walking late at night toward our hotel, a homeless person, apparently mentally troubled, walked toward us making aggressive gestures, shouted some curse words, and then run away. This was quite unpleasant, of course, but Mark's reaction was very revealing: he said, in trembling voice (in Russian): "Poor boy, you should be lying in a soft bed having a cup of warm soup instead of roaming the streets. What a cruel world!". RIP.

Vlad Shalaev and Alexandra Boltasseva
Purdue University, USA

Prof. Mark Stockman was a great colleague, a longtime friend, and a remarkable human being. Such a beautiful mind who will be terribly missed. He will always stay with us – in our hearts, our research, scientific papers, and heated discussions at every conference to come.

DinPing Tsai
The Hong Kong Polytechnic University

The first time I met Professor Mark Stockman was to listen to his talk at Lash Miller Chemical Laboratories, the University of Toronto, in 1993. At that time, we used a homemade photon scanning tunneling microscope to measure the optical near-field images on the samples of the fractal silver nanoparticle clusters. We experimentally found that enhanced optical near-field at localized hot spots of the fractal silver clusters with clear dependence of the polarization. A brilliant and eminent physicist, Professor Vladimir Shalaev as our team member, carefully calculated and simulated the oscillation of the collective electron at the hot spots of the fractal silver nanoparticle clusters, and advised us the fundamental physics at that time. Professor Martin Moskovits, our supervisor and mentor, who taught me how to chemically produce silver nanoparticles and fractal clusters, submitted these exciting research results to Physics Review Letters in 1993. Subsequently, Professor Mark Stockman published a research highlight article, "Photon Tunneling Microscope Reveals Local Hot Spots," in 1994 to discuss the importance of the localized surface plasmon discovered and reported in our Physical Review Letters paper. It happened before the word "plasmonics" was known to most people.

Professor Mark Stockman is a pioneering researcher in Plasmonics. He visited National Taiwan University, Academia Sinica, National Applied Research Laboratories, and National Tsing Hua University in Taiwan many times for invited lectures, tutorial courses, and conferences in the last 12 years. His talks always attracted lots of attention from local students, researchers, and professors working on Plasmonics related topics. Attached are the photos taken at the SPP8, Taipei in 2017.

Martin Wegener
Karlsruhe School of Optics & Photonics, Germany

Mark Stockman and I met at many conferences and especially at quite a few summer schools on Nanophotonics in Erice, where Mark and I became friends. At times, Mark sure struggled with the July heat in Sicily but he was always enthusiastic when it came to arguing about physics over uncounted glasses of his favorite Nero Davola, or singing “Bei mir bist Du scheen” when speaking about his wife. Typically, Mark gave five or more lectures on plasmonics in each of the summer schools. In one of these, he was standing on the stage and lecturing when his mobile phone rang. He picked up. His beloved wife was stuck at the airport in the US, trying to take off to Italy, when she realized her passport had expired. On the stage, his microphone unmuted, he suggested a solution. A few lectures later, on the stage, his phone rang again and we all learned that his suggestion had worked and that she actually made it to the planned flight. She safely arrived at Erice the next day. First things first.