The University of Electro-Communications

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Updates on research, innovation, and events at UEC:
Unique and Exciting Campus in Tokyo

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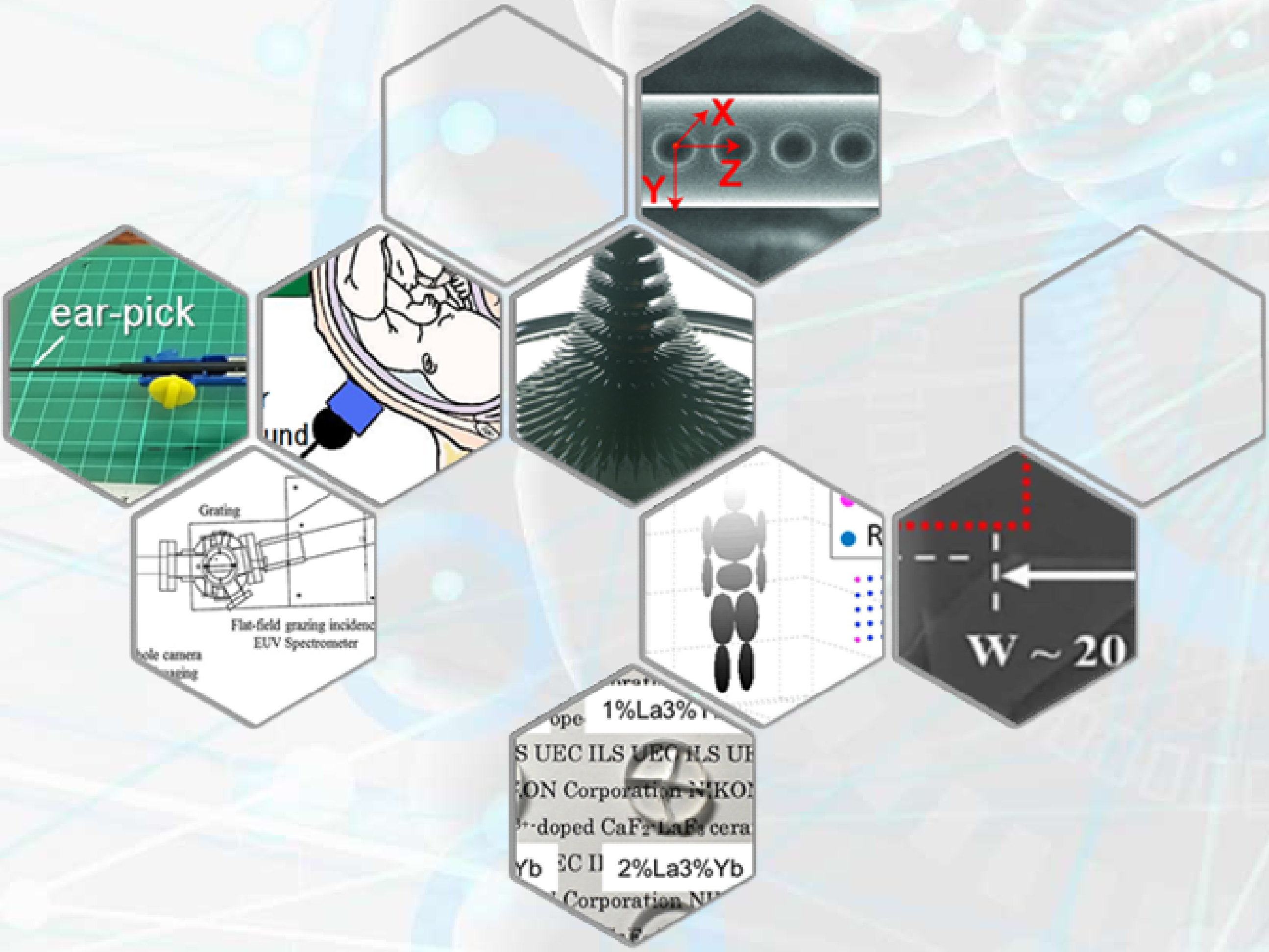

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Feature

- Frontiers of audiology: Quest to find effective solutions to support people with hearing loss

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- Astronomical spectroscopy in a laboratory: Direct and accurate measurements of electron densities of plasmas
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- Convergence of science and art: Three dimensional dynamics of ferrofluid sculptures

Frontiers of audiology: Quest to find effective solutions to support people with hearing loss

Takuji Koike,
Professor, Department of Mechanical and Intelligent Systems Engineering,
The University of Electro-Communications, Tokyo.

Takuji Koike is collaborating with medical doctors in Japan to clarify the origins of auditory problems as well as developing devices to support people suffering from hearing loss. "We are focusing on three main areas," says Koike. "Gaining insights into the mechanisms governing hearing disorders for the development of effective treatments; measuring the response of fetuses to sound; and developing hearing aids that are implanted into the bone behind the ear."

Specific projects

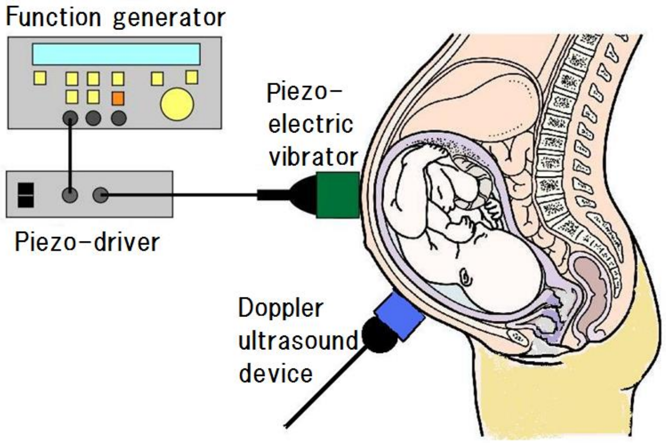
Modelling of auditory systems

Effective modelling is important to clarify the mechanisms of hearing disorders for the development treatments that cannot be studied by clinical research.

Koike and colleagues have devised numerical middle ear models and cochlear models for active motilities of the outer hair cells. Simulations are used to analyze vibrations of the lymph liquid and basilar membrane in the cochlea and clarify transmission mechanisms in the peripheral auditory systems. The simulations were used for clinical applications where the mechanisms of hearing losses caused by otosclerosis , perilymphatic fistula, and endolymphatic hydrops [1,2,3].

Measurement of auditory evoked response in fetus

One in eight hundred people in Japan suffer from congenital hearing loss that can lead to impairment of language development and handicap for clear conversation. In this research, Koike is working with medical schools in Japan to measure variation in the heart rate and brain waves of fetuses induced by vibratory stimulation applied to maternal abdominal wall. Initial experiments showed positive reactions from approximately 90% of the fetuses who were confirmed to have normal hearing after birth [4]. The set up consists of a piezoelectric vibrator to produce the sound and Doppler ultrasound device to detect changes in the heart rate.

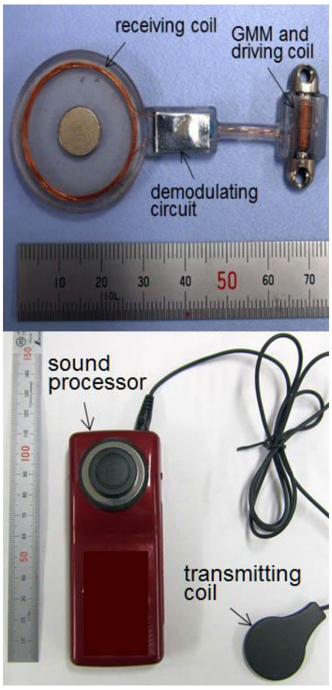


Set up for auditory evoked response in fetus

Response measured with Doppler device

Development of implantable bone conduction hearing aids

Koike's group has developed prototype bone-conduction hearing aid using Giant Magnetostrictive Material (GMM) vibrators. Improvements in the design of the vibrator and method of transdermal signal transmission yielded a device with higher efficiency compared to the existing bone-conduction hearing aids. "We have obtained a European patent for the basic specifications and operating function of the hearing aid and are working with a company to develop practical hearing aids," says Koike.

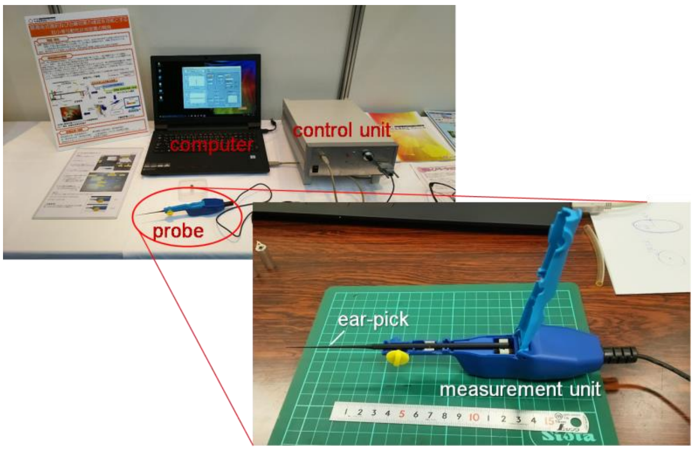


Prototype implantable bone conduction hearing aid.

Development of instruments to assist auditory surgeons during operations

Instruments for measuring ossicular mobility has been developed, and the ossicular mobility in patients has been measured during tympanoplasty. Some prototypes were built and tested in collaboration with medical equipment makers and medical institutions. This work was supported by Saitama Leading Edge Project (Medical Innovation).

"In the future, we will continue to develop ideas and instruments to improve the quality of life of people with auditory system problems," says Koike.



Ossicular mobility measuring device and system

References and further information

[1] Takuji Koike, Hiroshi Wada, Toshimitsu Kobayashi, *Modeling of the human middle ear using the finite-element. Method, J. Acoust. Soc. Am.* 111 (3), (2002).
[2] Takuji Koike, et al, Effects of a perilymphatic fistula on the passive vibration response of the basilar membrane. *Hear Res.* 283(1-2), 117-125 (2012)
[3] Sinyoung Lee and Takuji Koike, Simulation of the Basilar Membrane Vibration of Endolymphatic hydrops, *Procedia IUTAM* 24 (2017) 64 - 71.
doi: 10.1016/j.piutam.2017.08.043
[4] Rina Matsuoka, et. al, Piezoelectric vibrator-stimulated potential and heart rate accelerations detected from the fetus, *International Journal of Pediatric Otorhinolaryngology*, 101 (2017) 204e210.
http://dx.doi.org/10.1016/j.ijporl.2017.05.007
[5] Koike Laboratory
http://www.bio.mce.uec.ac.jp/

Professor: Takuji Koike (Dr. Eng. from Tohoku University, 1996/03)
Current research areas: Biomedical engineering, Biomaterials science and engineering, Dynamics, Control.
Current research subjects: Development of electromagnetic hearing aid, Measurement of ossicular mobility, Modeling of auditory system.
Personal website: http://www.bio.mce.uec.ac.jp/

Radar for environmental monitoring: New algorithms for high speed and low cost 3D imaging

Ultrawideband millimeter-wave radar devices are promising as high precision sensors to monitor environments where vision is hindered due to clouds and fog for applications including automobile collision avoidance systems. Importantly, during the identification of objects under such circumstances, raw data from the sensors must be rapidly and accurately processed into three dimensional images by so-called 'conversion algorithms'.

However, it is difficult to deal with the human body—which causes situations with rich interference—with conventional algorithms in terms of accuracy and computational cost.

Here, Shouhei Kidera at the University of Electro-Communications, Tokyo, and colleagues, have built on their previous research on the range points migration (RPM) method, and incorporates the Doppler velocity component with the RPM image for accurately generating 3D images with lower computational costs.

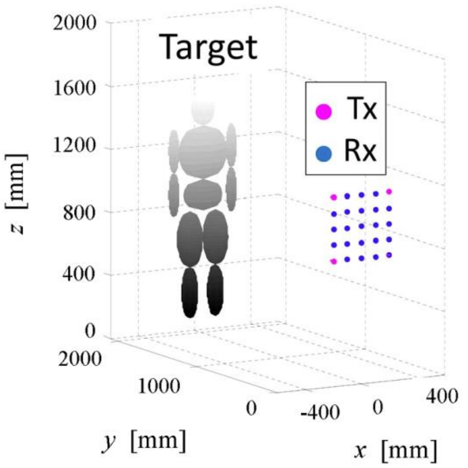
The researchers carried out numerical analysis assuming the multiple input multiple output (MIMO) radar with 140 GHz ultra wideband signals. Their method assumed a human body target, which consists of an aggregation of multiple ellipsoidal objects with different velocities.

The key aspect of the approach described by Kidara and his colleagues for improving the accuracy is that during conversion they select only a suitable set of so-called surrounding RPs (SubRPs) from all targeted range points (RPs), using Doppler based discrimination, which contributes a further target recognition issue.

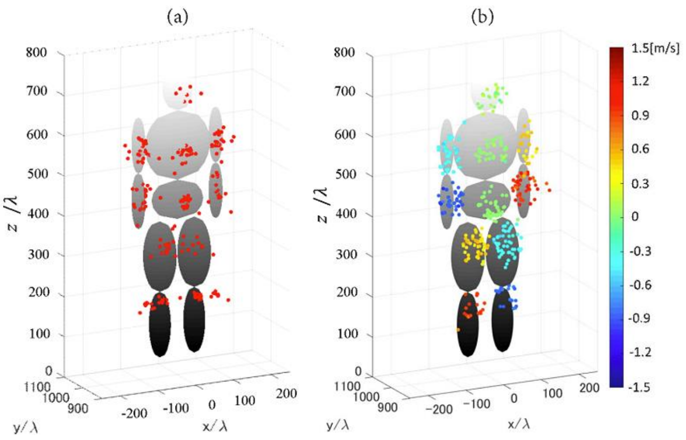
According to the researchers, further improvements in this method can be expected, "by introducing more efficient algorithm to search the optimal intersection points..... while the present algorithm relies on full search of possible intersection points."

Reference

Yuta Sasaki, Fang Shang, Shouhei Kidera, Tetsuo Kirimoto, Kenshi Saho, and Toru Sato "Three-Dimensional Imaging Method Incorporating Range Points Migration and Doppler Velocity Estimation for UWB Millimeter-Wave Radar". *IEEE Geoscience And Remote Sensing Letters*, Published online (8th December 2016); doi: 10.1109/LGRS.2016.2628909



Model used for testing the new algorithm.



Scattering center points in noiseless case: (a) obtained by the original RPM method, and (b) obtained by the proposed method (b).

Professor: Tetsuo Kirimoto (Ph. D. from Osaka University 1995/08)
Current research areas: Radar Signal Processing
Current research subjects: Imaging Radar, High Resolution Radar
Personal website: http://www.radar.ee.uec.ac.jp/english/

Associate Professor: Shouhei Kidera, (Ph. D. from Kyoto University 2007/09)
Current research areas: Microwave imaging / Signal processing
Current research subjects: Microwave mammography, Non-destructive testing, Human body imaging with radar
Personal website: http://www.ems.cei.uec.ac.jp/kidera/index_e.html

Assistant Professor: Fang SHANG (Ph.D. from The University of Tokyo 2014/09)
Current research areas: Synthetic aperture radar data interpretation
Current research subjects: Vegetation classification using polarimetric synthetic aperture Radar data
Personal website: http://www.irs.lab.uec.ac.jp/member/shangfang/

Graduate Student: Yuta Sasaki (Master degree from UEC 2016/03)
Current research areas: Signal processing
Current research subjects: Human body imaging with radar

Astronomical spectroscopy in a laboratory: Direct and accurate measurements of electron densities of plasmas

Isaac Newton's discovery in the mid-1600s that white light consists of a 'spectrum' of rainbow colors, and then in the early 1800s Joseph von Fraunhofer's observation of lines in the solar spectrum laid the foundations for modern day spectroscopy—the workhorse of astronomers analyzing the chemical compositions of plasmas that form the basis of stars and galaxies.

Recently, astronomers are particularly interested in accurate measurements of the electron density of thermal plasmas to determine the evolution of the universe. The electron density is determined by measuring the relative intensities of two characteristic spectral lines that fluctuate with electron density. However, in practice it is challenging to obtain accurate density dependent ratio measurements with ground based instruments, which is critical for verifying space based observations.

Here, Erina Shimizu and Safdar Ali at the University of Electro-Communications, Tokyo, and colleagues, report on experimental measurements of electron density dependent lines ratios of highly charged Fe X, XI and XII—ions for which there are discrepancies between astrophysical observations and theoretical simulations.

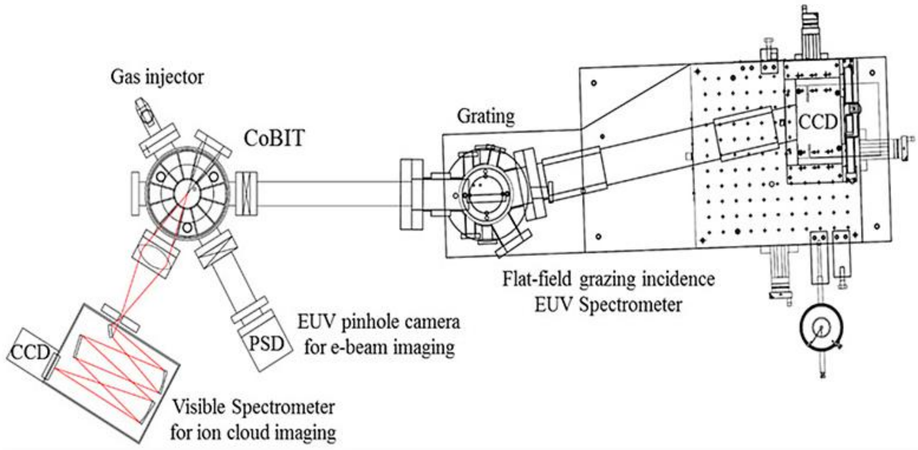
The measurements were made using a flat field grazing incidence spectrometer in the extreme ultraviolet (EUV) spectral wavelength range 16 to 20 nm. The researchers state: "Rather than estimating electron density from the theoretical electron beam width as reported previously...we obtained it experimentally by directly imaging electron beam and observing spatial distribution of the trapped ions."

Notably, the research yielded good agreement between the experimental and theoretical calculations—findings attributed to the determining electron densities experimentally with a combination of a pin hole camera and visible spectrometer.

References

Erina Shimizu, Safdar Ali, Takashi Tsuda, Hiroyuki A. Sakaue, Daiji Kato, Izumi Murakami, Hirohisa Hara, Tetsuya Watanabe, and Nobuyuki Nakamura. "Measurements of density dependent intensity ratios of extreme ultraviolet line emission from Fe X, XI, and XII" *Astronomy and Astrophysics*, Published online (25th March 2017); doi: 10.1051/0004-6361/201630199

https://www.aanda.org/articles/aa/abs/2017/05/aa30199-16/aa30199-16.html



Schematic drawing of the experimental system used in this study.

Associate Professor: Nobuyuki, NAKAMURA (Ph.D. from The University of Electro-Communications 1996/03)
Current research areas: Atomic/Molecular/Quantum electronics
Current research subjects: Physics of highly charged ions, Highly charged ions, Atomic structure, Surface modification with highly charged ions, Highly charged ions, Surface modification
Personal website: http://yebisu.ils.uec.ac.jp/nakamura/index.html

Former Graduate Student: Erina, SHIMIZU (Master of Engineering from the University of Electro-Communications 2016/03)
Former research subject at the graduate school of the UEC: Laboratory measurements of highly charged iron ion spectra relevant to astrophysical plasmas

Former JSPS postdoctoral fellow: Safdar, ALI (Ph.D. from Stockholm University 2012/05)
Former research subject at Institute for Laser Science of UEC: Measurements of extreme ultraviolet spectra of highly charged ions

Laser science: Innovative solid state lasers with Yb^{3+}-doped CaF_2 - LaF_3 ceramic gain media

Polycrystalline ceramic materials offer advantages including robustness over conventional glass as gain media for solid state lasers: devices that find many applications such as laser processing and medical surgery.

Recently, there has been renewed interest in fluoride ceramics lasers for ultrashort pulse laser oscillators/amplifiers. Here, Shotaro Kitajima at the University of Electro-Communications, Tokyo, Hitoshi Ishizawa at Nikon Corporation, and colleagues report on the development of the first Yb^{3+}-doped CaF_2-LaF_3 ceramic laser with a maximum power output of 4.36 W and slope efficiency of 69.5%.

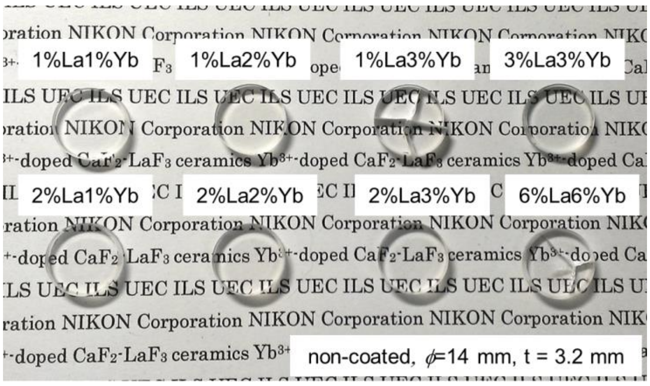
Kitajima and colleagues fabricated CaF2 ceramics doped with two rare earth ions of La and Yb from 1 at. % La^{3+}, 1 at. % Yb^{3+} to 6 at. % La^{3+}, 6 at. % Yb^{3+}. The doping was carried out using a wet process to mix CaF_2 with two kinds rare-earth fluorides with average diameters of 200 nm. This was followed by sintering first between 750°-900° in air followed by the hot isostatic pressing method between 700°-1000° in an inert atmosphere.

Notably, the random orientation of the axes of grains in ceramics improves their mechanical robustness, which is one of the main motivations for producing CaF_2 ceramics for gain media.

The findings described in this paper show that it may be possible to significantly improve the physical properties of Yb: CaF_2-ceramic materials for high performance laser gain media.

Reference

Shotaro Kitajima, Kentaro Yamakodo, Akira Shirakawa, Ken-Ichi Ueda, Yoshinobu Ezura and Hitoshi Ishizawa "Yb^{3+}-doped CaF_2-LaF_3 ceramics laser" *Optics Letters*, Published online (31st March 2017); doi: 10.1364/OL.42.001724
https://doi.org/10.1364/OL.42.001724



Yb:CaF_2-LaF_3 ceramic samples with different combinations of doping concentrations.

Associate Professor: Akira Shirakawa(Ph. D. from University of Tokyo 1999/03)
Current research areas: Laser Engineering / Quantum Electronics
Current research subjects: High power solid-state / fiber lasers, Coherent beam combining
Personal website: http://www.ils.uec.ac.jp/~shirakawa_lab/

PhD Student: Shotaro Kitajima
Current research areas: Laser Engineering
Current research subjects: Thin-disk ultrashort pulse laser, investigation of new laser materials
Personal website:
http://www.ils.uec.ac.jp/~shirakawa_lab/http://www.ils.uec.ac.jp/~shirakawa_lab/member.html#phd

Two dimensional materials: Advanced molybdenum selenide near infrared phototransistors

Optical sensors operating in the near infrared (NIR) are important for applications in imaging, photodetectors, and biological sensors. Notably, recent reports on the synthesis of high quality, large areas of graphene has motivated researchers to search for other 2D materials with properties suitable for NIR devices.

Now, Abdelkader Abderrahmane and colleagues at the University of Electro-Communications, Tokyo in collaboration with researchers at Chosun University, Korea, describe the optoelectronics characteristics of molybdenum selenide (MoSe2) phototransistors for applications to photodetectors. The application of gate voltages to the devices yielded a maximum photoresponsivity 238 A/W, an external quantum efficiency (EQE) of 37,745% under 785 nm light. The researchers state: "our device is one of the best high-performance nanoscale near-infrared photodetectors based on multilayered two-dimensional materials."

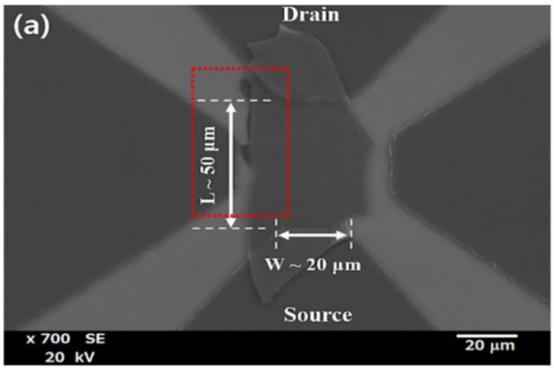
The devices were fabricated using few layered MoSe2 with a thickness of ~44 nm that was exfoliated from natural MoSe2 onto thermally oxidized silicon substrates with metallic strips acting as back gates. The transistor channel width and length were 50 and 20 μm, and the charge mobility was be 5.1 cm2 /V/s.

Electrical measurements indicated that the devices operated in the so-called accumulation mode and with a pinch off voltage of - 40V.

The combination of the 1.1 eV bandgap of $MoSe_2$ and its high optical absorption compared to MoS_2 is expected to offer wide ranging applications in optoelectronics.

Reference

Pil Ju Ko, Abdelkader Abderrahmane, Nam-Hoon Kim and Adarsh Sandhu, "High-performance near-infrared photodetector based on nano-layered MoSe2." *Semiconductor Science and Technology*. Published online (22nd May 2017)
doi: 10.1088/1361-6641/aa6819



Scanning electron microscopy image of the near-infrared photodetector based on few-layered $MoSe_2$.

Project Assistant Professor: Abdelkader Abderrahmane (Doctor of Engineering in Electrical and Electronic Information Engineering from Toyohashi University of Technology, 2014/09)

Current research areas: Magnetic control of micro and nanorobots, Development of electronic nanodevices.

Current research subjects: Soft nanorobots, Electronic and optoelectronic devices, Two-dimensional materials.

Nanophotonics: Integrating nanocavities into optical fibers with femtosecond laser ablation

Controlling and manipulating the interaction of light with nanostructures offers the promise of new and innovative technological applications ranging from nanolasers and sensors to quantum computing. However, in spite of tremendous advances in nanotechnology that has enabled the fabrication of one and two dimensional structures (such as photonic crystal cavities), efficiently integrating nanocrystal cavities with modern optical fibers in communications networks is proving to be difficult.

Here, Kohzo Hakuta and colleagues at the University of Electro-Communications, Tokyo, report on the realization of one dimensional arrays of nanometer sized holes or 'nano-craters' on the surfaces of optical nanofibers by simply irradiating them with a single pulse of ultrashort light from a femtosecond laser. These so called 'nanofiber based photonic crystal cavities' are expected to find new applications in nanophotonics and quantum information science.

Specifically, the researchers used a laser with a 400 nm wavelength and 120 fs pulse width to ablate thousands of 50 - 250 nm-diameter nanocraters with a periodicity of 350 nm over a 1 mm length in 450 - 550 nm-diameter nanofibers. Notably, in this procedure the nanofiber acts as a lens and focuses the incident laser light onto its 'shadow side', and the use of only one pulse eliminates structural imperfections due to mechanical vibrations.

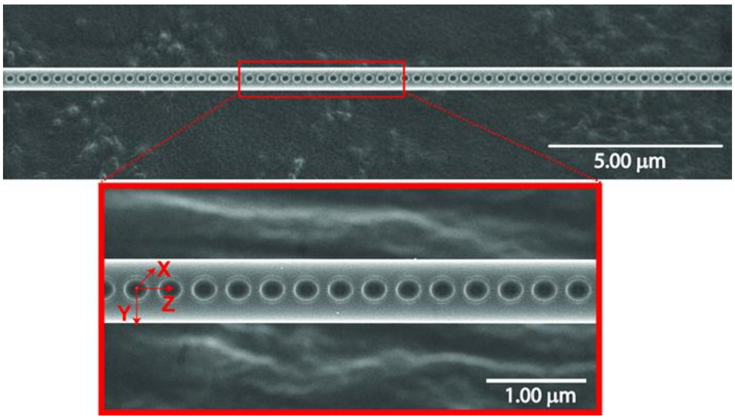
The resulting one dimensional photonic cavities exhibited strong broadband reflectance and high optical transmission. The researchers state: "The strong confinement of the field, both transverse and longitudinal, in the nanofiber-based PhC cavities and the efficient integration to the fiber networks, may open new possibilities for nanophotonic applications and quantum information science."

Reference

Kali Prasanna Nayak , Jameesh Keloth and Kohzo Hakuta. "Fabrication of 1-D Photonic Crystal Cavity on a Nanofiber Using Femtosecond Laser-induced Ablation." *Journal of Visualized Experiments*, published online (25th February 2017)

doi:10.3791/55136

Video of the experiment: http://www.cpi.uec.ac.jp/researchActivities.html



Scanning electron microscopy image of the resulting uniformity and dimensions of photonic crystals induced on nanofibers using femtosecond laser-induced ablation.

Professor: Kohzo, Hakuta (Ph.D. from The University of Tokyo 1974)
Current research areas: Atomic/Molecular/Optical physics, Quantum Electronics, Quantum Optics, Nanophotonics
Current research subjects: Optical Nanofibers for Quantum Photonics
Personal website: http://www.cpi.uec.ac.jp/index.html

Associate Professor: Kali Prasanna, Nayak (Ph.D. from The University of Electro-Communications 2009)
Current research areas: Quantum Optics, Nanophotonics
Current research subjects: Interfacing single atoms/photons on optical nanofiber cavity

Present Doctor Course Student: Jameesh, Keloth (Master of Science from University of Hyderabad 2011)
Current research subjects: Developing optical nanofiber cavity for quantum photonics

Convergence of science and art: Three dimensional dynamics of ferrofluid sculptures

Sachiko Kodama
Associate Professor
University of Electro-Communications, Tokyo.

Sachiko Kodama is an artist internationally recognized for her renderings unique and dynamic three dimensional sculptures including "Protrude Flow" (2001), "Morpho Tower" (2006), and "Pulsar" (2008) by controlling the intricate interaction of magnetic field lines with solutions of dark and optically reflective ferrofluids.

Sachiko has a bachelor's degree in physics. She decided that she was more interested in art than physics for her doctorate. "During my PhD program I studied digital art in the form of 3D computer graphics and holography," says Sachiko. "However, I was interested in the interaction of light with real 3D materials. Holography did not offer this but ferrofluids did. So after finding inspiration from work by Minako Takeno on ferrofluids, I launched the "*Protrude, Flow*" project in 2000. The work from this collaboration was exhibited at Siggraph 2001 Art Gallery."


Protrude, Flow 2001

"***Protrude, Flow***" was an interactive exhibition where a computer was used to move ferrofluids into "organic wild shapes". The exhibition used ferrofluids and six electromagnets, and the shapes of the ferrofluids were affected by the sounds generated by visitors in the exhibition room. The dynamic movements of the ferrofluids were projected onto a large screen in the room in real time.

Link to video of "Protrude Flow"
https://www.youtube.com/watch?v=c4rLG5Aaie4

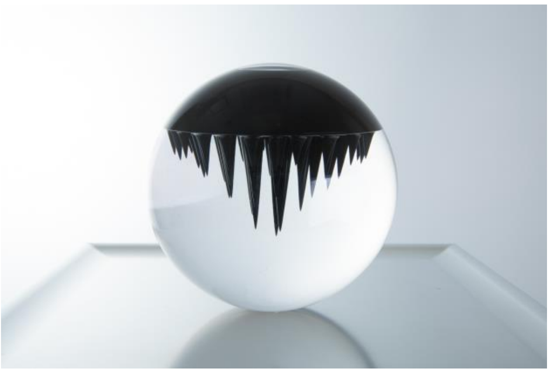
In contrast to the dynamic movement of ferrofluids in "***Protrude, Flow***", the "Pulsate" series was focused on using the ferrofluid "as a place where thoughts mingled together". The "*Pulsate -Melting Time, Dissolving Time*" exhibition was set up in a large white room with a white dish containing black ferrofluid placed at the center of a white table with some chairs around it. The sounds of voices and footsteps of visitors caused the fluid to 'pulsate' gently in synchronization


Morpho Tower

with the sounds. For larger sounds, the fluid moved with larger amplitudes, and at a certain point the ferrofluid "erupted" into the air. An electromagnet placed under the table was used as the actuator.

The experience of creating these dynamic structures led Sachiko to test new ideas for producing even more dynamic ferrofluid sculptures. Specifically, Sachiko experimented with electromagnets with pre-sculptured iron cores. This set up was used for the creation of the "*Breathing Chaos*" (2004) and "*Morpho Tower*" (2006) series. The important point is that the shapes and movement of "spikes" in the ferrofluid was controlled by varying the current flowing through the electromagnet.

Links to videos of "Breathing Chaos" and "MorphoTower" series.
Breathing Chaos:
https://www.youtube.com/watch?v=AkiIt2OeQ_g
Morpho Tower:
https://www.youtube.com/watch?v=6eIcynuzg2M
Morpho Towers/Two Standing Spirals:
https://vimeo.com/78180852



Planet No.1

"A major goal is to create a human torso," explains Sachiko.
"This is very challenging because the ferrofluid must move upwards against gravity. I am also considering colored ferrofluids. So, still many avenues to explore."

Further information

1. October 2017: Exhibition in Kyoto
   Sachiko Kodama - *Éblouissan*, 6 October - 25 November 2017, Seikado Gallery, Kyoto, Japan
   http://sachikokodama.com/722-2/
2. http://sachikokodama.com/
3. Sachiko Kodama: Dynamic Ferrofluid Sculpture: Organic Shape-changing Art Forms, CACM(Communications of the ACM), Volume 51, Issue 6, pp.79-81, June 2008.

Associate Professor: Sachiko Kodama (PhD in Art from University of Tsukuba, 2000/03)
Current research areas: New media art
Current research subjects: Interactive art studies using magnetic fluid, Art and information technology,
Personal website: http://www.kodama.hc.uec.ac.jp/index-e.html

The University of Electro-Communications (UEC) in Tokyo

is a small, luminous university at the forefront of pure and applied sciences, engineering, and technology research. Its roots go back to the Technical Institute for Wireless Commutations, which was established in 1918 by the Wireless Association to train so-called wireless engineers in maritime communications in response to the Titanic disaster in 1912. In 1949, the UEC was established as a national university by the Japanese Ministry of Education, and moved in 1957 from Meguro to its current Chofu campus Tokyo.

With approximately 4,000 students and 350 faculty, UEC is regarded as a small university, but with particular expertise in wireless communications, laser science, robotics, informatics, and material science, to name just a few areas of research.

The UEC was selected for the Ministry of Education, Culture, Sports, Science and Technology (MEXT) Program for Promoting the Enhancement of Research Universities as a result of its strengths in three main areas: optics and photonics research, where we are number one for the number of joint publications with foreign researchers; wireless communications, which reflects our roots; and materials-based research, particularly on fuel cells.

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