Boğaziçi Üniversitesi

PHYSICS DEPARTMENT SEMINAR

"From fluctuations to emergent patterns - Part I: The fat fingers problem and atomic-scale 3D printing"

Abstract: Exactly 30 years ago IBM scientists spelled IBM with 35 individual atoms. However, an atomic-scale 3D printer, like the Replicators of Star Trek, remains a matter of science fiction. Why? We identify three fundamental challenges to present approaches: (1) The state of the art is based on lasers, but optical wavelengths are much larger than atoms. We call this the "Fat Fingers problem". (2) Even a 1-mm^3 object has 10^22 atoms, *i.e.*, we face an explosion of complexity on the way "down". (3) Fluctuations become exceedingly strong with decreasing sizes. We believe the present approach of so-called direct writing is hopeless.
Our approach follows the principles laid out by I. Progogine and H. Haken in the 1960s and 1970s. Our implementation was inspired by mode-locking of lasers, whereby modes that lock up in phase experience preferential "gain" over having random phases, and a coherent structure in time emerges spontaneously out of (vacuum) fluctuations. We apply the same principle to create self-organized patterns on the surfaces or inside the volume of various materials. We show that the size of the laser beam no longer determines the smallest structures we can control, eliminating the fat fingers problem. The resulting structures can be controlled by only a few parameters, the countless rest are locked nonlinearly, avoiding an explosion of complexity. Fluctuations can be harnessed to help create these structures (discussed in part II of these lectures). Although there are countless technical challenges, we see no fundamental impediment to 3D printing at atomic resolution.

Bio:Dr. F. Ömer Ilday received the BS degree in theoretical physics from Boğaziçi University, Istanbul, Turkey, in 1998. He took his PhD in applied physics from Cornell University, Ithaca, NY, USA, in 2003. He worked at Massachusetts Institute of Technology (MIT) from 2003 to 2006. In 2006, he joined Bilkent University as faculty member. He was awarded the European Research Council's prestigious Consolidator Grant in 2013, the first consolidator grant and the first ERC grant on basic science in Turkey. Dr. Ilday graduated valedictorian of the top-ranked Physics Department at Bogazici University in 1998. His contributions to science have been generously recognized through various awards. He received the prestigious RLE Fellowship from MIT (2003), the Findlay Award from Cornell University (2004), the Outstanding Young Scientist Award from the Turkish Academy of Sciences (TÜBA-GEBIP) (2006), the Teşvik Award from the Scientific and Technological Research Council of Turkey (TÜBİTAK) (2011), the Engin Arık Science Award from the Turkish Physical Society (2012), the received the top award in science in Turkey, the Science Award of TÜBİTAK (2017). He is a full member of the Science Academy of Turkey and a senior member of the Optical Society of America.

F. Ömer Ilday
Bilkent University

"From fluctuations to emergent patterns - Part II: Universal dissipative self-assembly"

Abstract A Holy Grail of self-assembly research is to develop a general methodology applicable to almost any material, from the smallest to the largest scales, whereby qualitatively identical results are obtained independently of initial conditions, size, shape, the function of the constituents. In this talk, I will first qualitatively describe how the triple mechanism of nonlinearity, fluctuations and feedback mechanisms gives rise to complexity in systems driven far from equilibrium: Nonlinearity to give rise to multiple fixed points in phase space during dynamic evolution (hence, the possibility of multiple steady states), each corresponding to a different pattern and their bifurcations; positive and negative feedback to cause exponential growth of perturbations and their suppression and stabilization, respectively; fluctuations to spontaneously induce transitions through bifurcations. I will further argue that the ensuing complex dynamics can be controlled through controlling the energy source driving the system away from equilibrium. Then, I will showcase the methodology on a diverse spectrum of materials starting from simple, passive, identical quantum dots (few-hundreds of atoms large) that experience extreme Brownian motion and up to complex, active, non-identical human cells (~10^21 atoms large) with sophisticated internal dynamics. The autocatalytic growth curves of the self-assembled aggregates are shown to scale identically, and interface fluctuations of the growing aggregates are universal obeying the Tracy-Widom distribution. I will further showcase potential applications of our method and demonstrate its absolute control at relevant spatial and temporal scales.

Bio: Dr. Serim Ilday received her BS degree in Chemistry from Selçuk University, Konya, Turkey, in 2003. She then worked as a project coordinator in the Ministry of Health, Turkey between 2004-2007 while working toward her MS degree in Chemistry at Ankara University, Ankara, Turkey. Upon receiving her MS degree in 2007, she moved to Bilkent University to work as a researcher in two industrially funded projects for 3 years. She later received her PhD degree in Micro and Nanotechnology from Middle East Technical University, Ankara, Turkey, in 2014. She worked in the Physics Department at Bilkent University, Ankara, Turkey, from 2014 to 2017 as a Research Fellow. In December 2017, she took a faculty position also at Bilkent University. Her research focuses on self-assembly, complexity, far from equilibrium systems, nonlinear and stochastic dynamics, adaptive hierarchical materials, emergent phenomena. Her work has been published in prestigious journals including Nano Letters, Nature Communications, Nature Photonics, and recently highlighted in the media including Phys.org, MIT Tech News, Science Daily, IEEE Spectrum, Optics & Photonics News and Nanowerk. She is the recipient of 2018 L'Oreal-UNESCO For Women in Science award.

Serim Ilday

Bilkent University

DATE : February 20, Wednesday 2019

TIME : 14:30

PLACE : Feza Gürsey Seminar Room

Coffee will be served at 14:00