

# Kendiliğinden organize sistemler, fiber lazerler, ve hızlandırıcılar

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<http://ultrafast.bilkent.edu.tr>

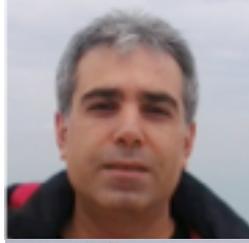
# Ultrahızlı Optik & Lazerler Laboratuvarı (UFOLAB)

- Doğrusal olmayan, yitirgen, dengeden uzak sistemler
- Kip-kilitli lazer dinamikleri
- Kendiliğinden organizasyon ve kendiliğinden kurulum
- Ultrahızlı lazerlerin biyomedikal uygulamaları



# Ultrahızlı Optik and Lazerler Laboratuvarı (UFOLAB)

## Bilim insanları



Dr. Parviz Elahi



Dr. Hamit Kalaycıođlu



Dr. Ihor Pavlov



Dr. Onur Tokel

## Doktora Öğrencileri



Tesfay Teamir



Denizhan K. Kesim



Ahmet Turalı

## Yüksek Lisans Öğrencisi



Özgün Yavuz

## Proje Yöneticisi



Gizem Erkilet

## Araştırma Mühendisi



Önder Akçaalan

## Postdoklar

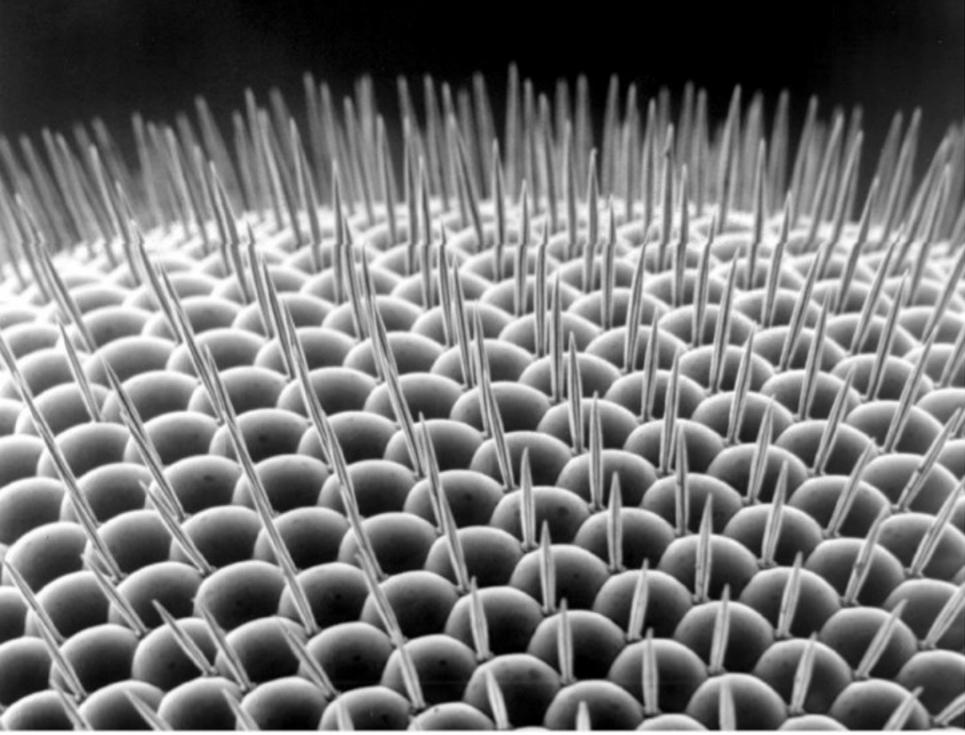


Dr. Ghaith Makey



Dr. Huihui Li

# Bilimsel Hedef



Doğada, **yapı / işlevsellik** çoğunlukla **olasılıksal** etkiler **altında doğrusal olmayan geribesleme** mekanizmalarından doğuyor.



# Nonlinearity Engineering:

Bu dinamiklerden faydalanarak,  
minimal müdahale ile

kendiliğinden organize sistemleri yönlendirmek

Interplay of:

Çatallanmalar (bifurcations)

Geribesleme döngüleri

Salınımlar (fluctuations)

## Çatallanmalar (bifurcations)

Çatallanmalar, salınımlar & sönümlenme zaman simetrisini kırıyor.

## Geribesleme döngüleri

## Salınımlar (fluctuations)

## Çatallanmalar (bifurcations)

### Geribesleme döngüleri

Pozitif geribesleme salınımları yüksetliyor.

Negatif geribesleme kararlılaştırıyor.

### Salınımlar (fluctuations)

Çatallanmalar (bifurcations)

Geribesleme döngüleri

Salınımlar (fluctuations)

Gürültü kontrol için kullanılabilir.

# Örnek sistemler

Zayıf stokastik etkiler, güçlü doğrusal olmayan etkiler

- Nonlinearity management in mode-locked lasers
- Creating rich, 2D patterns on various surfaces
- Nonlinear non-local feedback for creating 3D structures inside Si
- Controlling dissipative systems via structured noise
- Ablation-cooled laser material removal

Güçlü stokastik etkiler, zayıf doğrusal olmayan etkiler

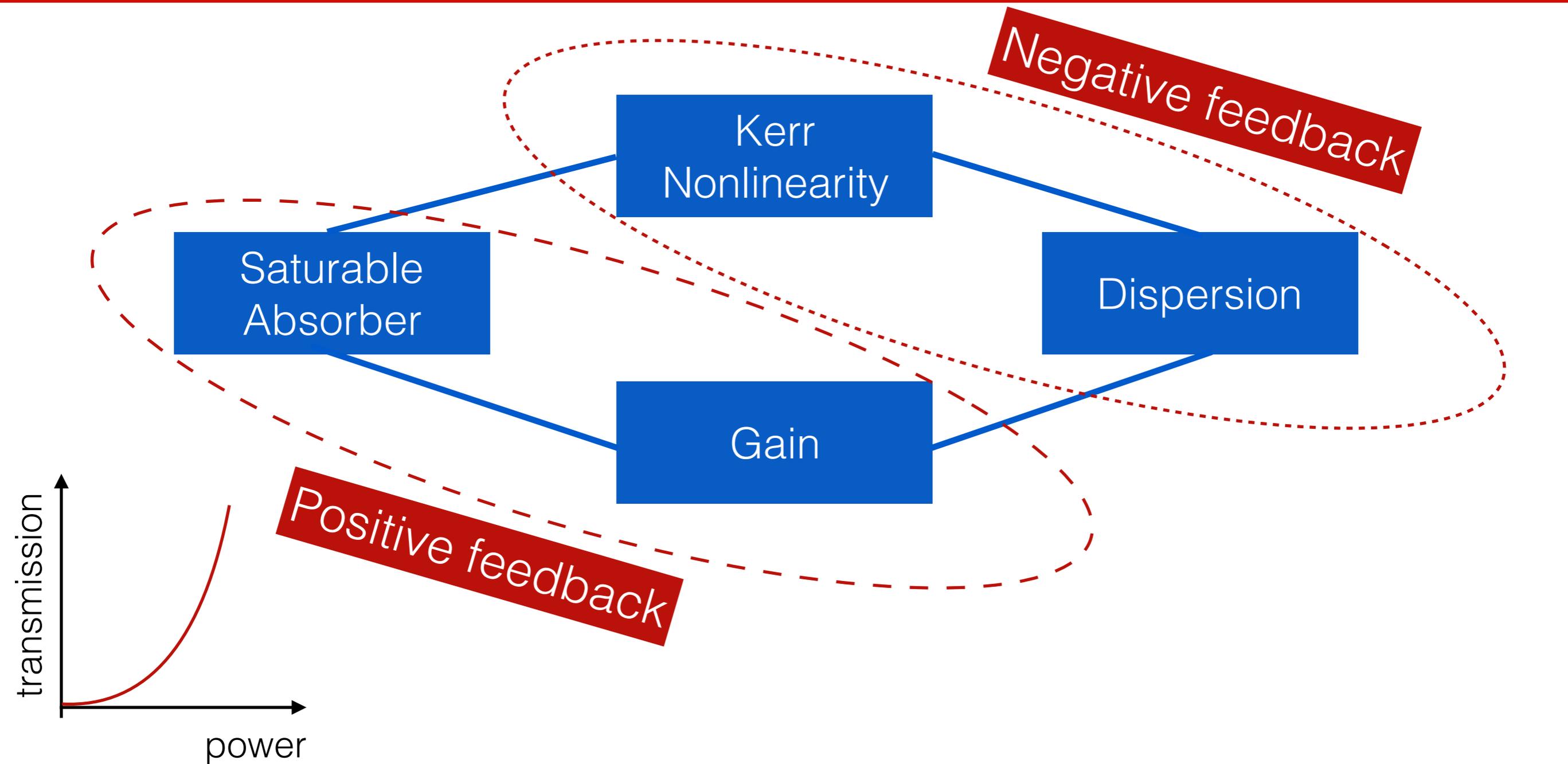
- Static self-assembly of a nanomaterial

Güçlü stokastik etkiler ve güçlü doğrusal olmayan etkiler

- Dynamical self-assembly of colloidal nanoparticles

**Dengeden uzak bir sistem olarak kip-kilitlemeli lazerler**

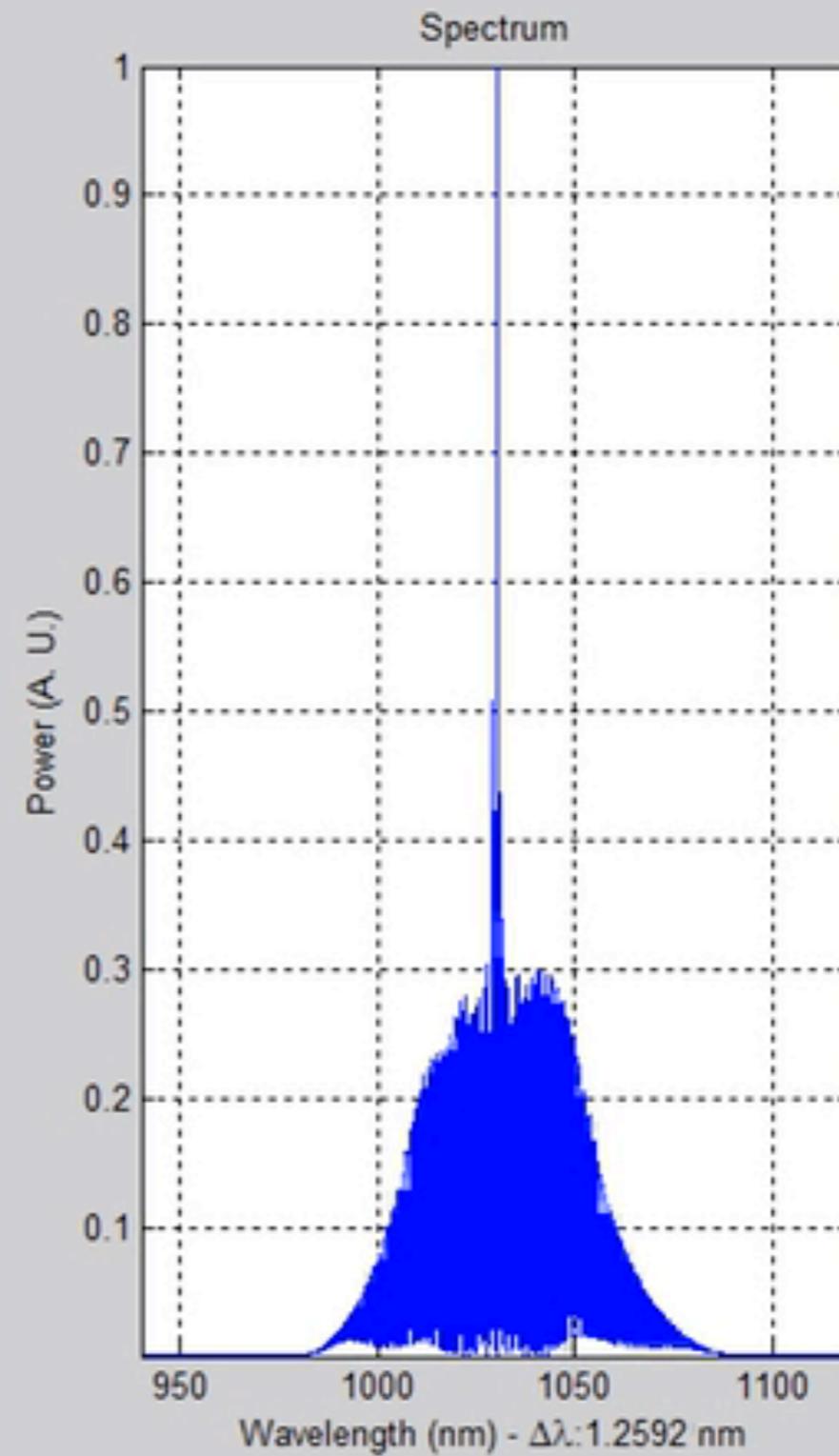
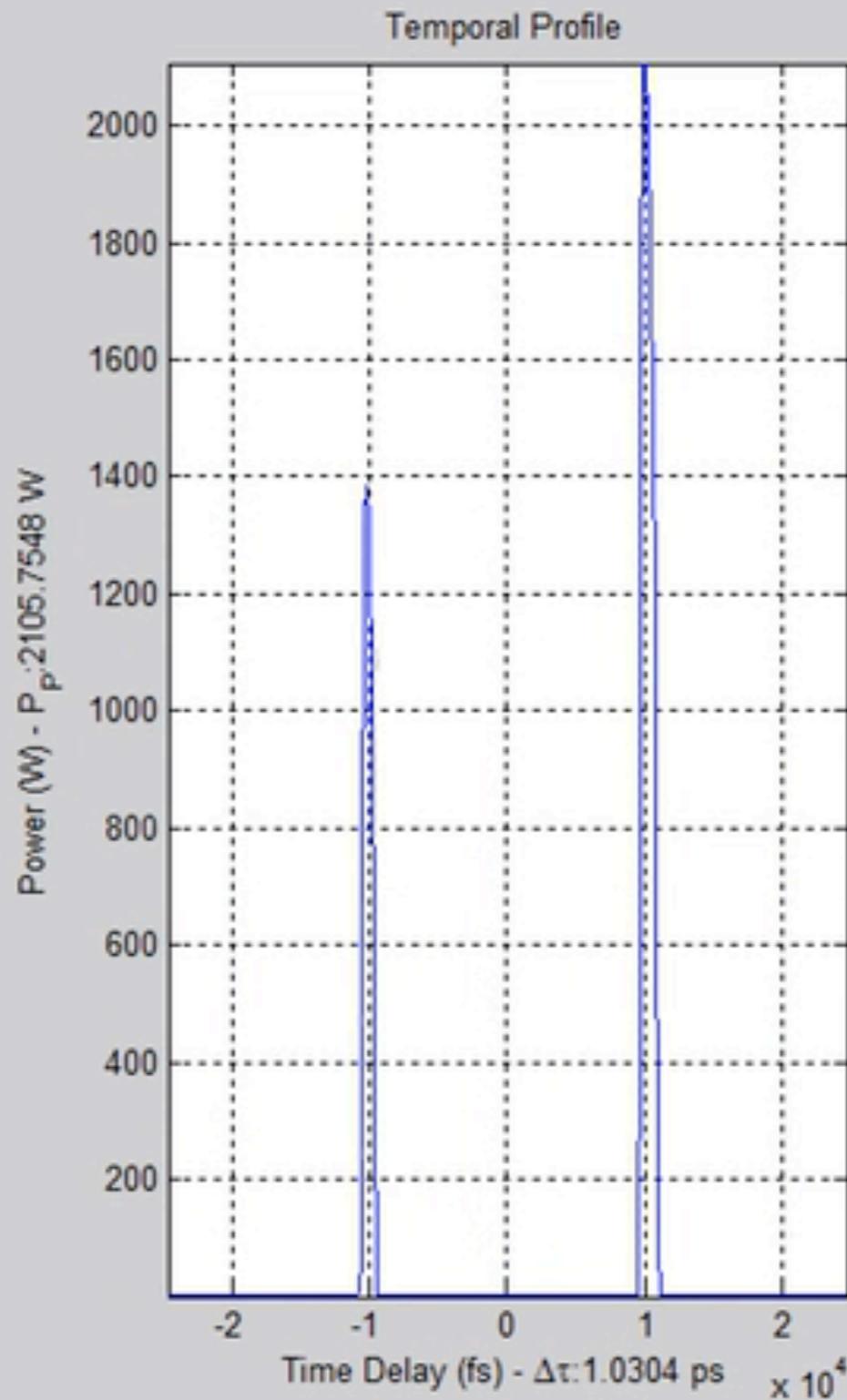
# Kip kilitlemeli lazerler ile femtosaniye atımlar elde ediyoruz



$$i\partial_z u + D(z)\partial_{tt}u + \gamma(z)|u|^2u = i(g(z) + g_\omega(z)\partial_{tt}u + \delta(z)|u|^2u)$$

Nonlinear feedback leads to temporal localization.

# Olasılıksal salınımlardan lazer atımının doğumu



## Nonlinearity management: a route to high-energy soliton fiber lasers

Fatih Ö. Ilday and Frank W. Wise

*Department of Applied Physics, Cornell University, Ithaca, New York 14853*

Received May 29, 2001; revised manuscript received August 27, 2001

We propose the use of self-defocusing nonlinearities to control nonlinear phase shifts in soliton fiber lasers. By analogy to dispersion management, we refer to this scheme as nonlinearity management. First we describe a map that can be regarded as a combination of nonlinearity management and dispersion management. The map is designed to support solitons in two segments of alternating sign of nonlinearity and dispersion. Analytical and numerical calculations demonstrate that this map can be essentially free of spectral-sideband generation. Suppressing the spectral sidebands should make possible pulse energies 100 times greater than those of existing soliton fiber lasers. We also discuss the less than ideal case of direct reduction of average nonlinearity by use of self-defocusing nonlinearity segments without optimizing dispersion. The second scheme has the advantage of easier implementation. Practical implementations with existing materials are discussed. © 2002 Optical Society of America

# Wave-breaking-free laser

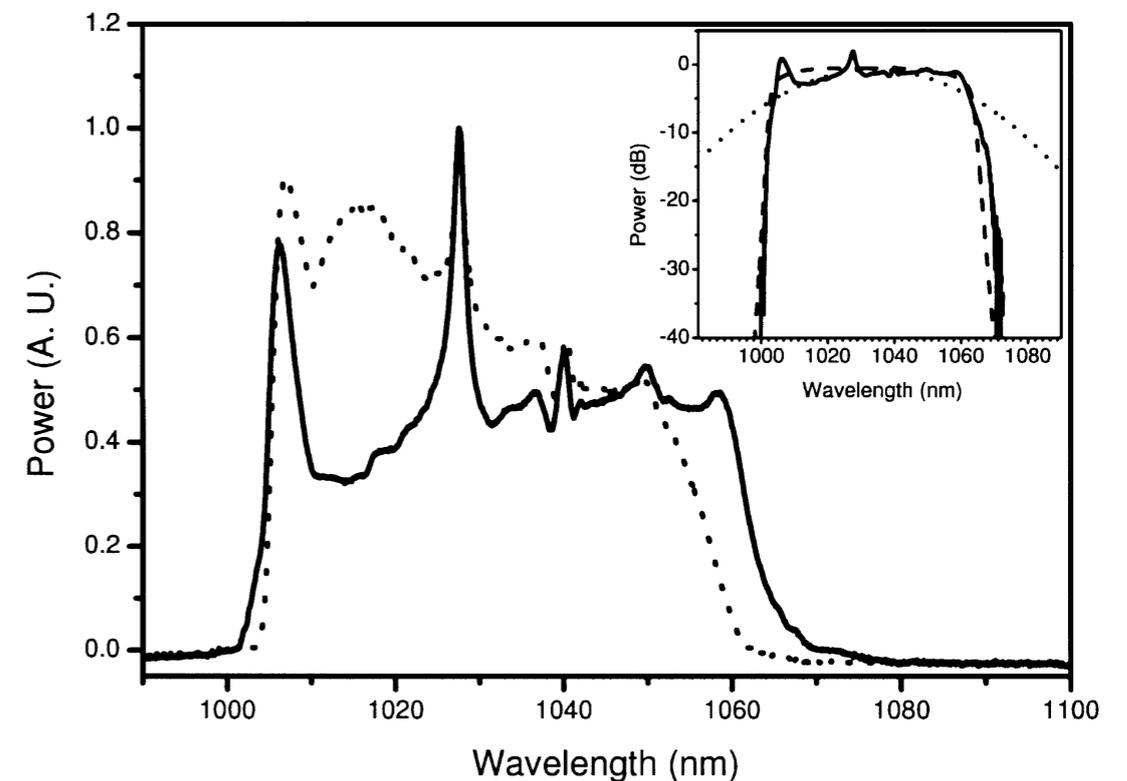
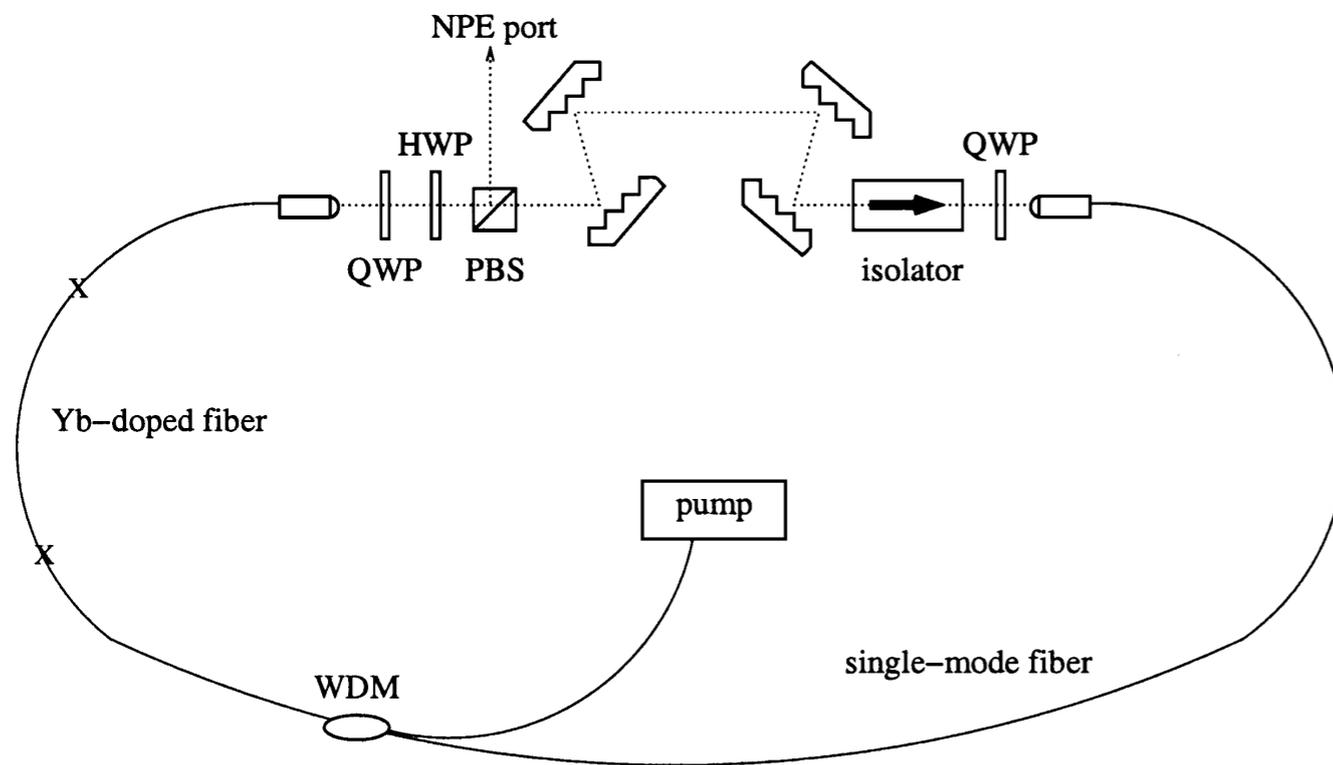
August 1, 2003 / Vol. 28, No. 15 / OPTICS LETTERS

1365

## Generation of 50-fs, 5-nJ pulses at 1.03 $\mu\text{m}$ from a wave-breaking-free fiber laser

F. Ö. Ilday, J. R. Buckley, H. Lim, F. W. Wise, and W. G. Clark

*Department of Applied Physics, Cornell University, Ithaca, New York 14853*

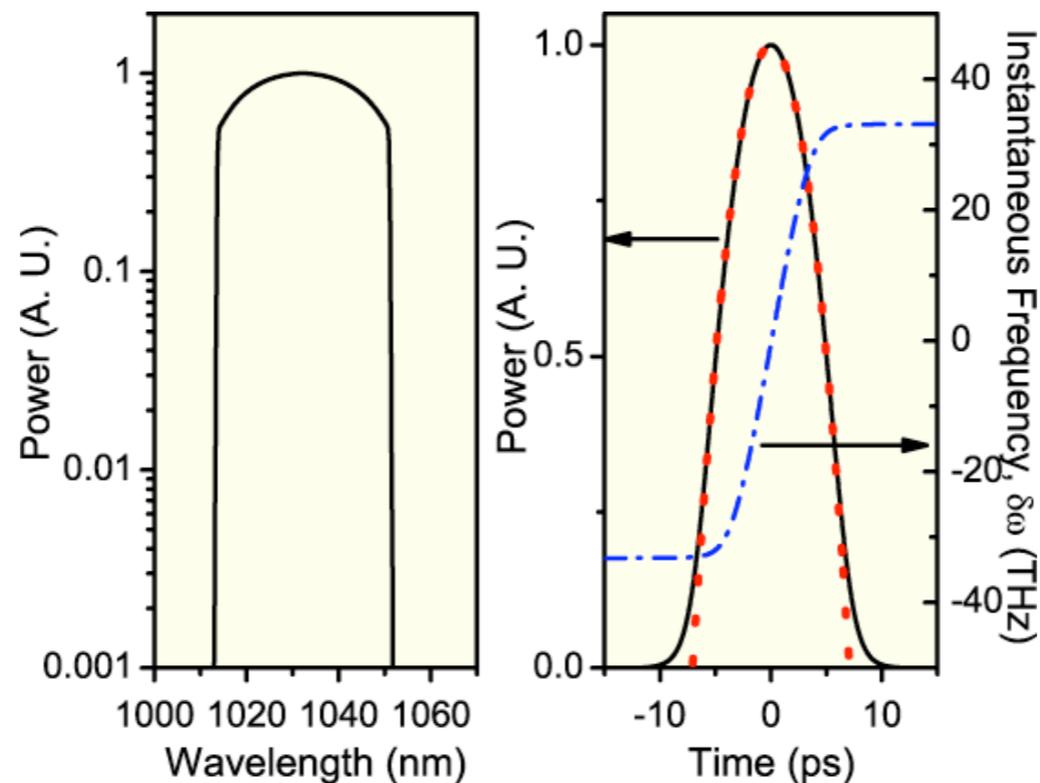


## Self-Similar Evolution of Parabolic Pulses in a Laser

F. Ö. Ilday,<sup>1,\*</sup> J. R. Buckley,<sup>1</sup> W. G. Clark,<sup>2</sup> and F. W. Wise<sup>1</sup>

<sup>1</sup>*Department of Applied Physics, Cornell University, 212 Clark Hall, Ithaca, New York 14853, USA*

<sup>2</sup>*Clark-MXR Inc., Dexter, Michigan 48130, USA*



self-similar propagation

dispersive propagation

normal GVD, NL

gain,  $\Delta\lambda$

SA

anomalous GVD

# İlk soliton-similariton lazeri

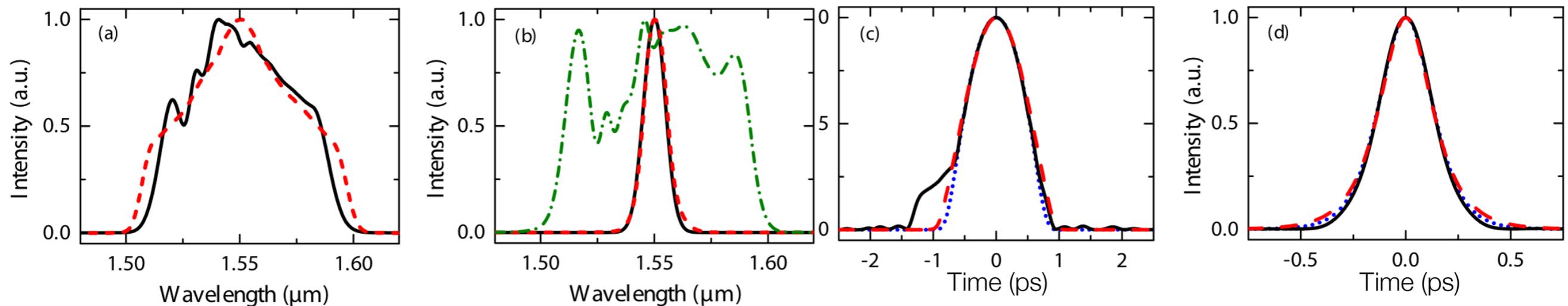
nature  
photonics

LETTERS

PUBLISHED ONLINE: 21 MARCH 2010 | DOI: 10.1038/NPHOTON.2010.33

## Soliton-similariton fibre laser

Bulent Oktem<sup>1</sup>, Coşkun Ülgüdür<sup>2</sup> and F. Ömer Ilday<sup>2\*</sup>



Black lines experiment, red lines simulation, blue lines analytic.

self-similar propagation

soliton propagation

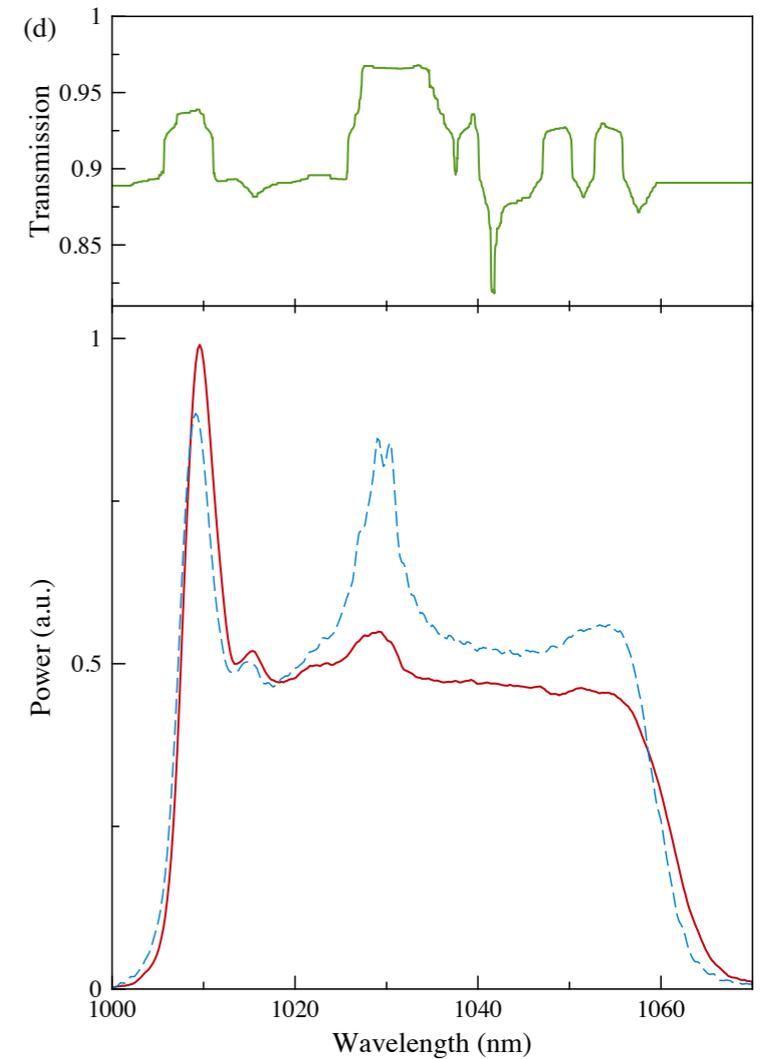
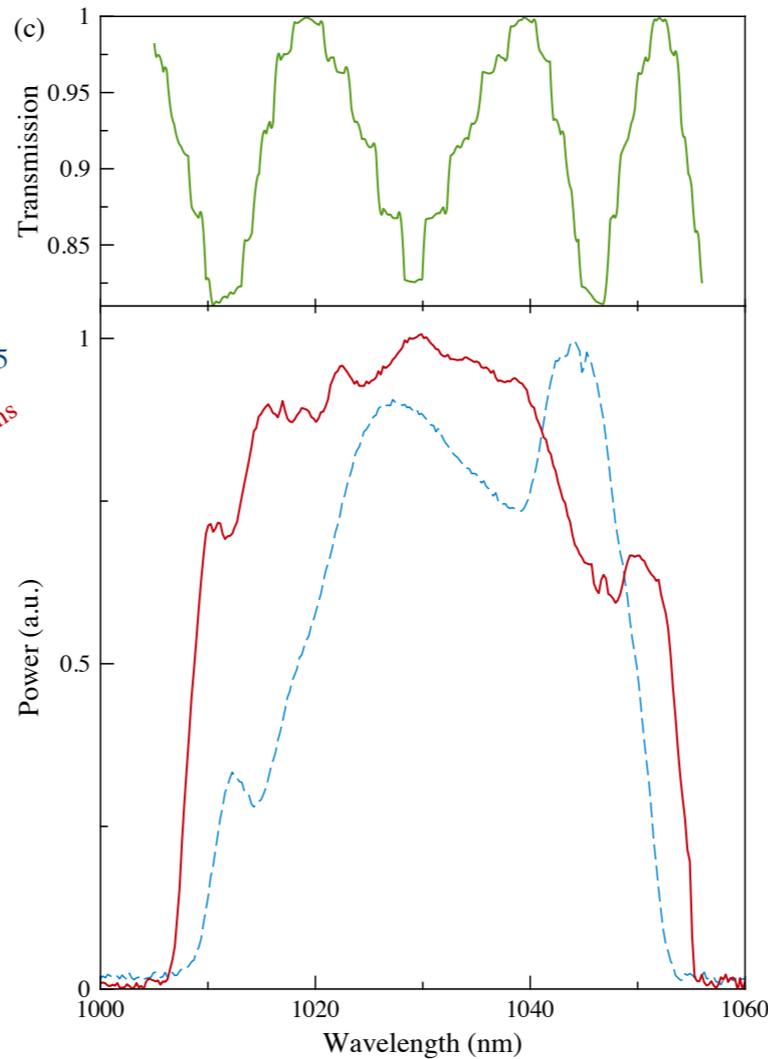
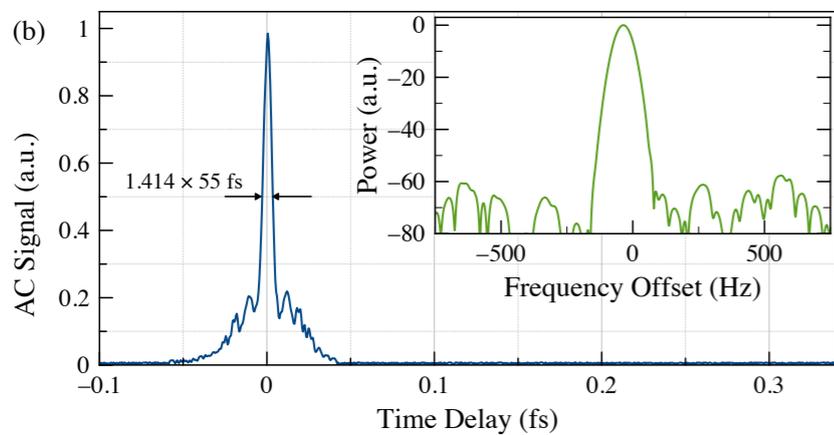
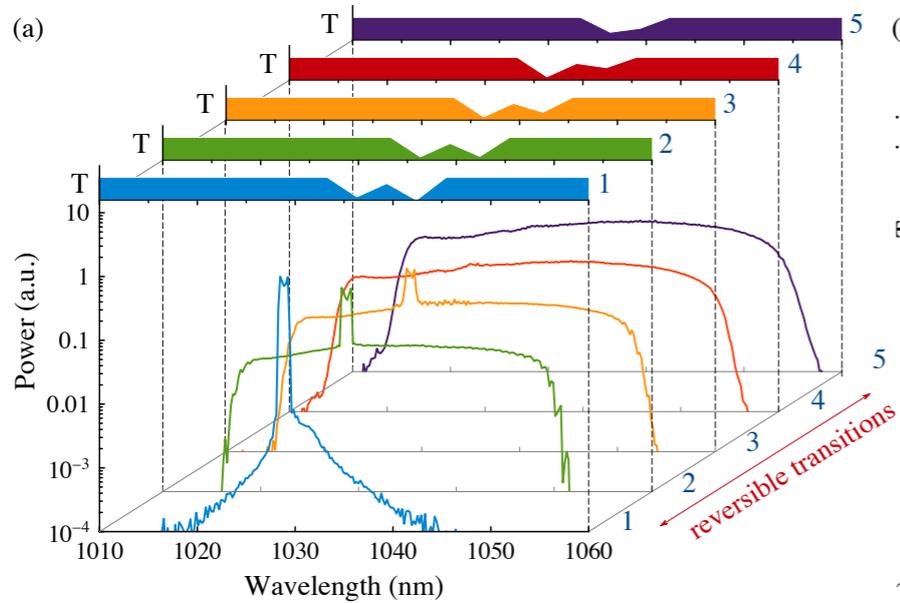
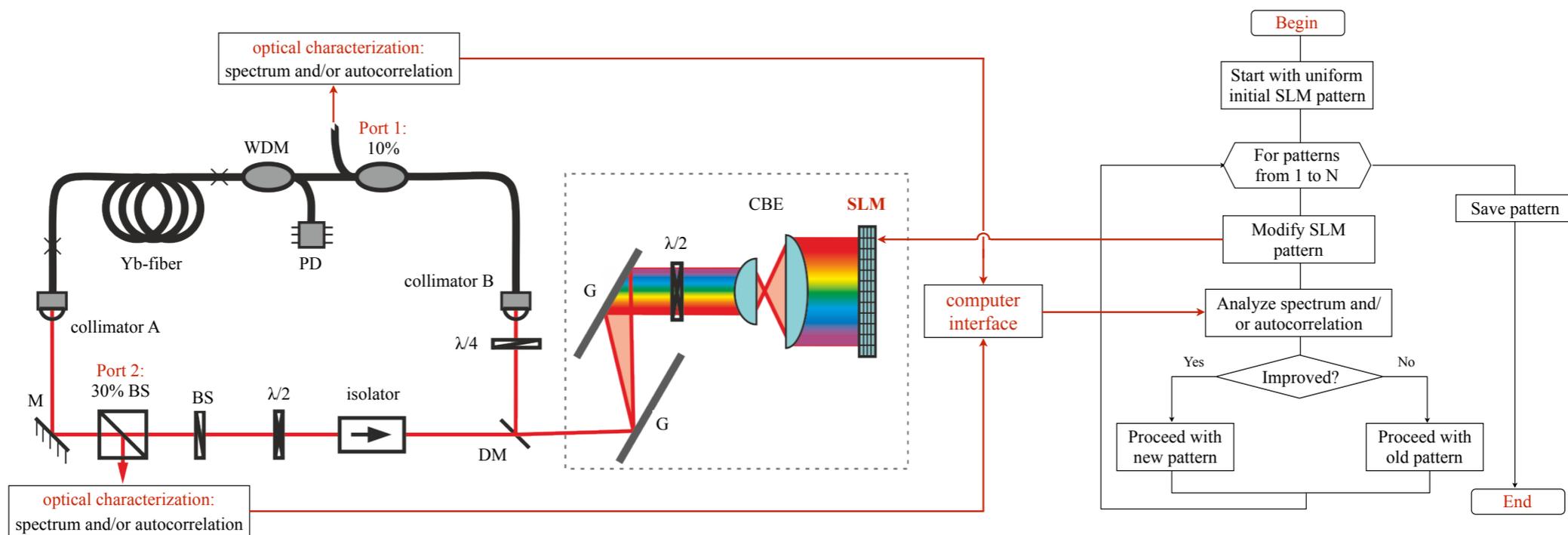
normal GVD, NL, gain

$\Delta\lambda$

SA

anom. GVD, NL

# İstatistik fizik için uygun: elektronik kontrollü $10^{19} \times 200$ hal

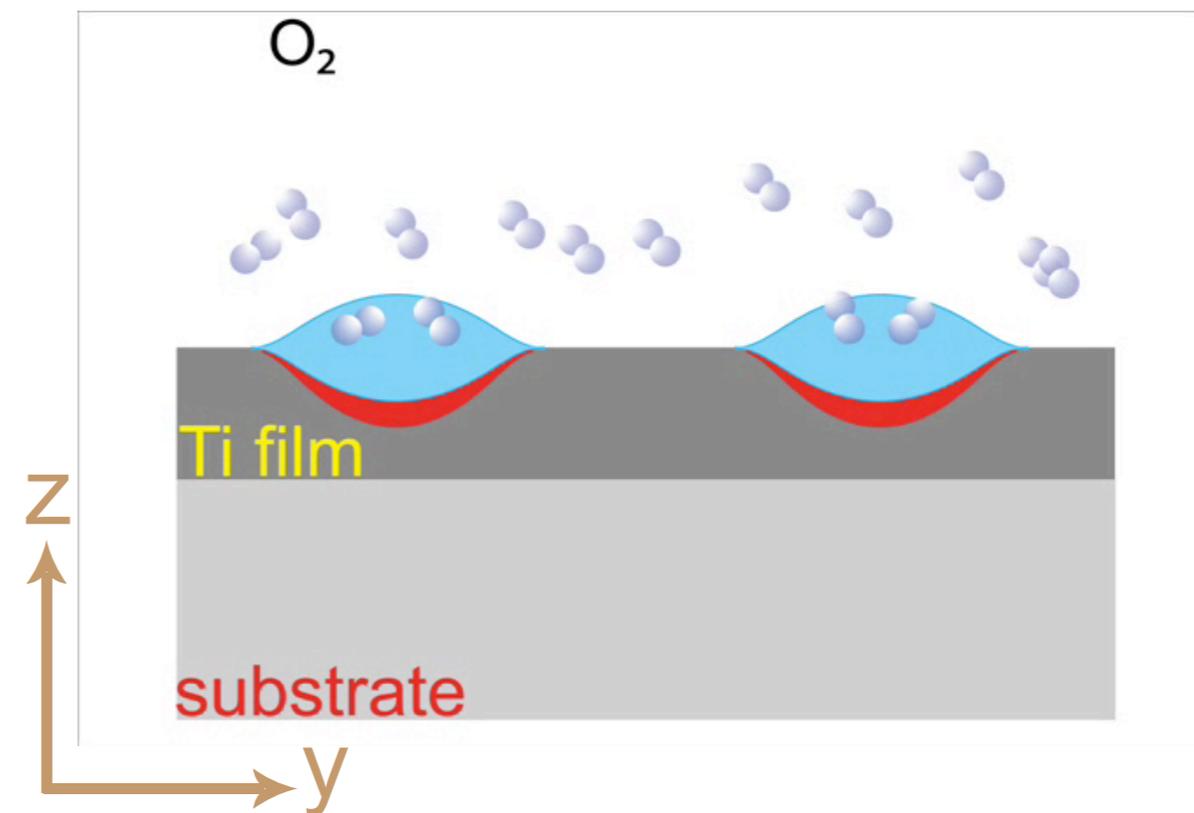
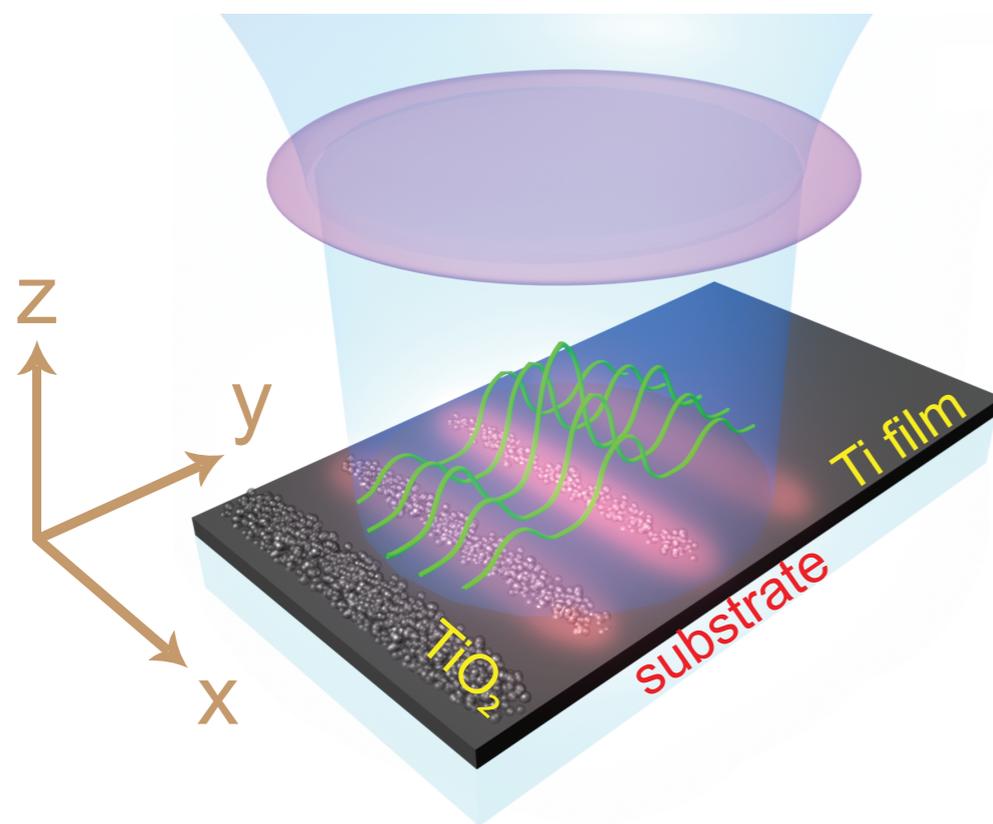


# Nonlinear Laser Lithography

yüzeylerde (2B) kendiliğinden organize yapılar

# Nonlinear Laser Lithography (NLL)

- 1: Pulse scatters from surface, leading to localized field enhancement.
- 2: Surface material is ablated at field-enhanced points, reacting with  $O_2$  to form an oxide.
- 3: Oxide piles on, blocking access of  $O_2$  to newly activated surface material.

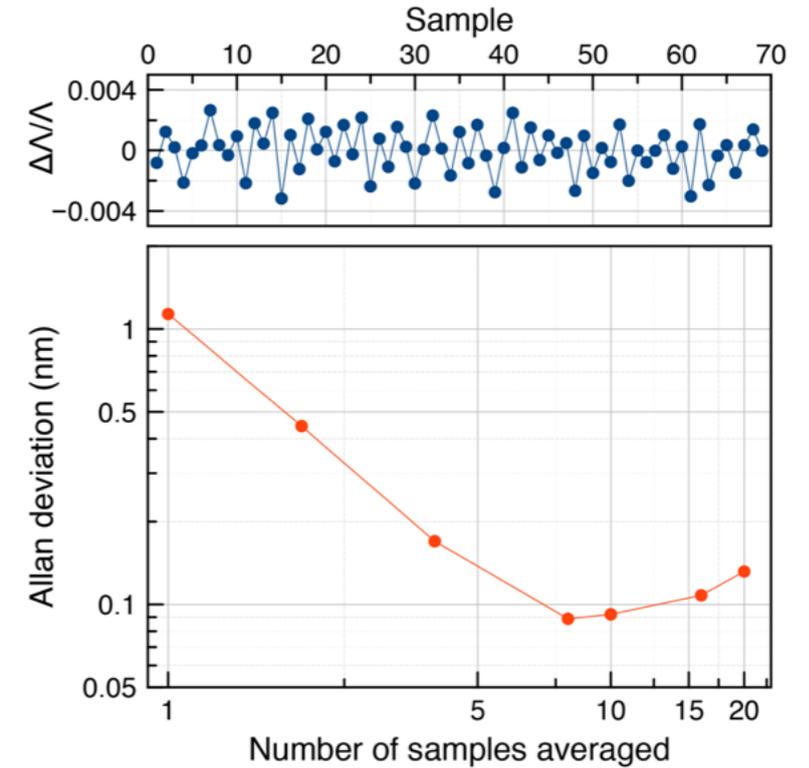
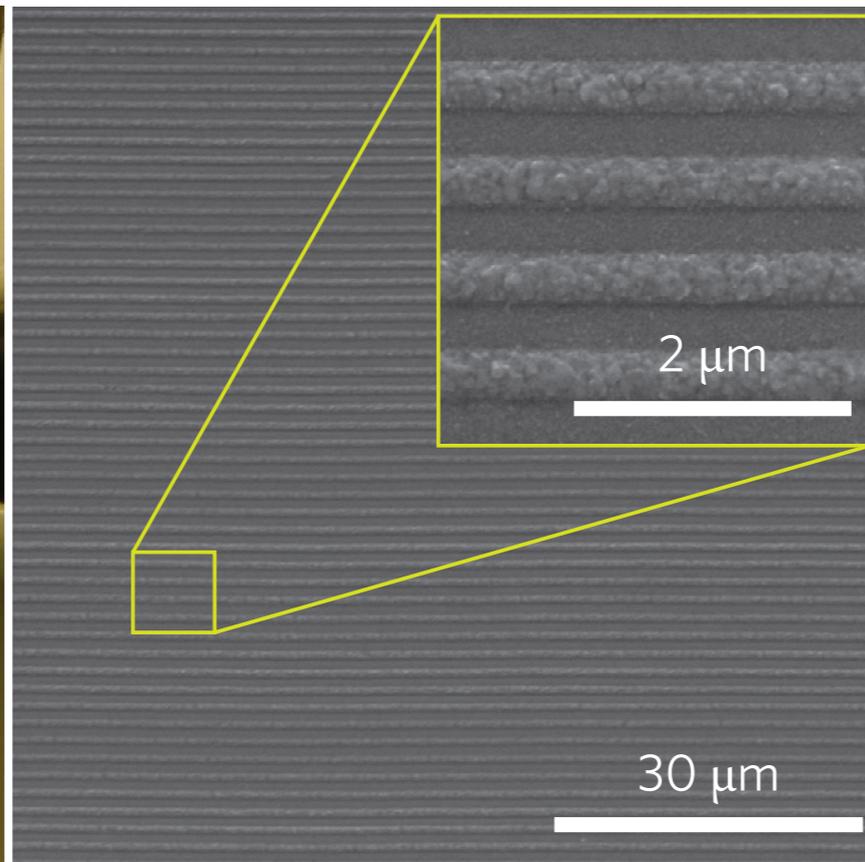
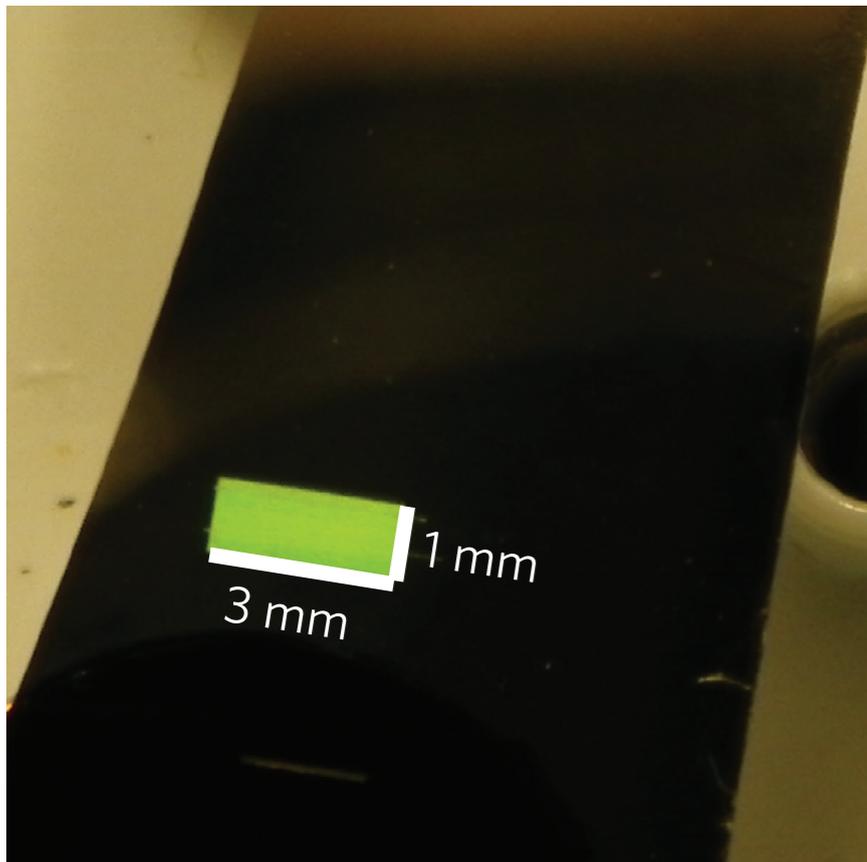


Steps 1 & 2 form + feedback.

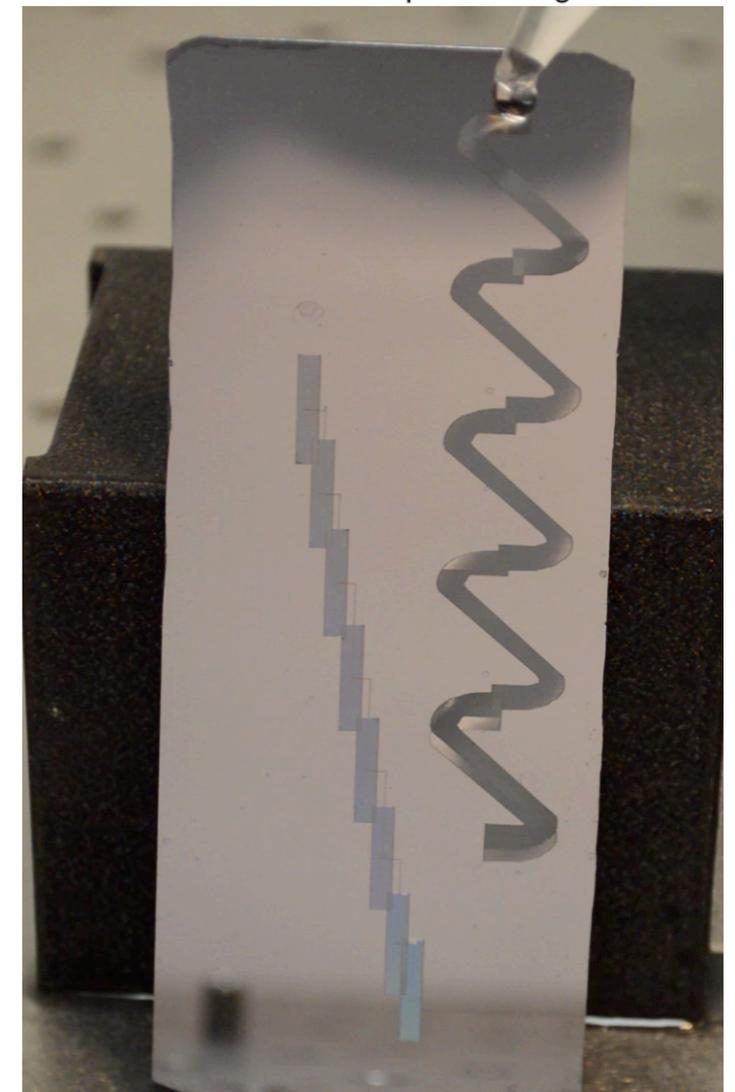
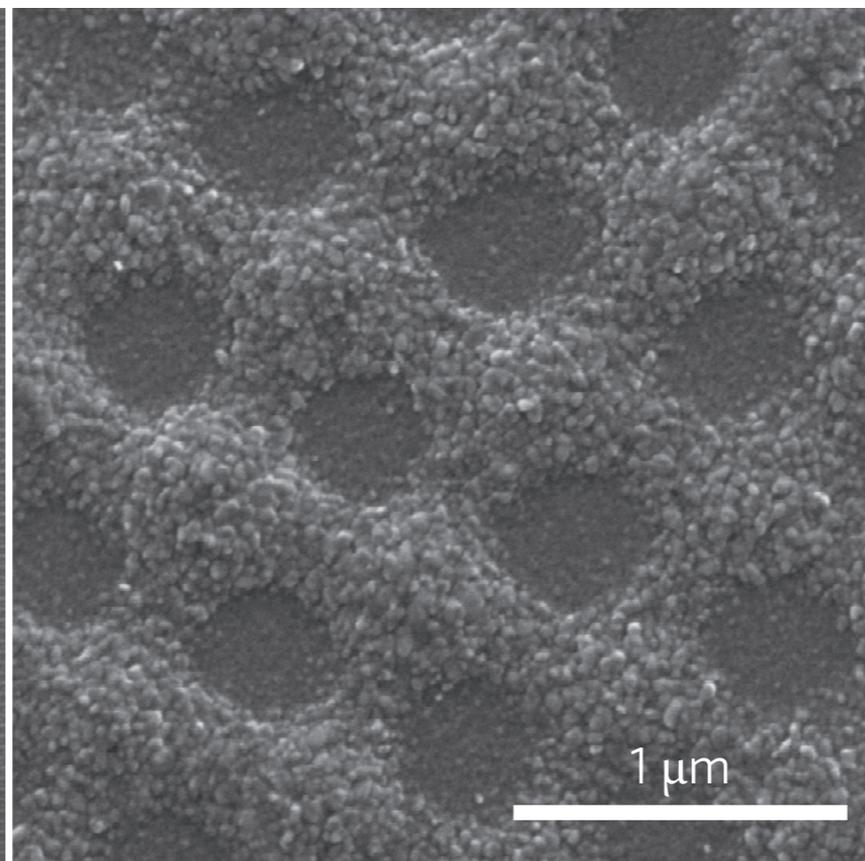
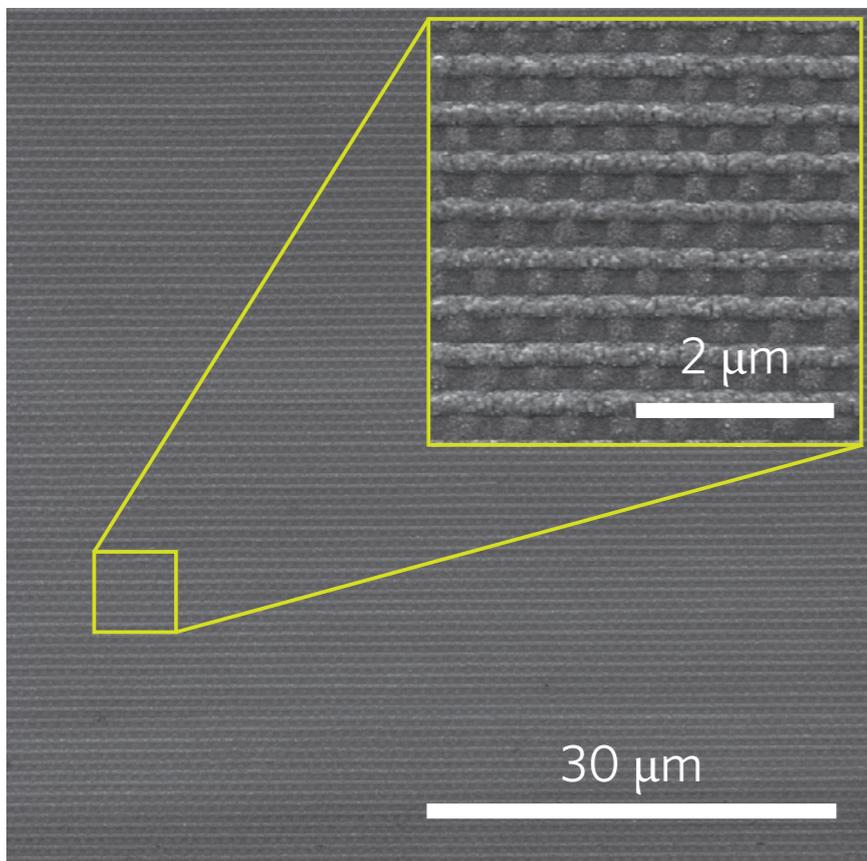
Steps 2 & 3 form - feedback.

# Çeşitli nano yapılar (8 saniyede 1 cm<sup>2</sup> alan)

a

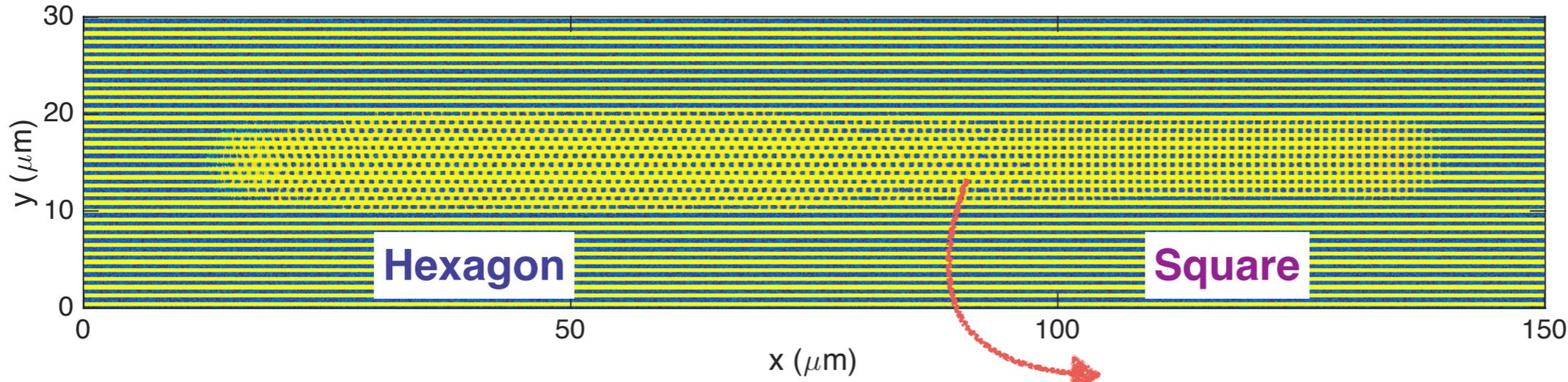


c

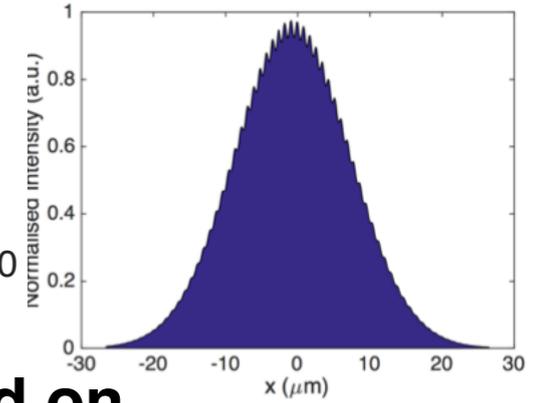


# Kendiliğinden organizasyonu "yapılandırılmış gürültü" ile kontrol

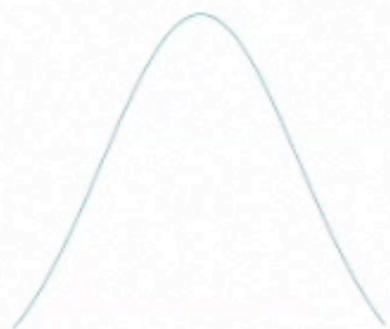
White noise added to surface



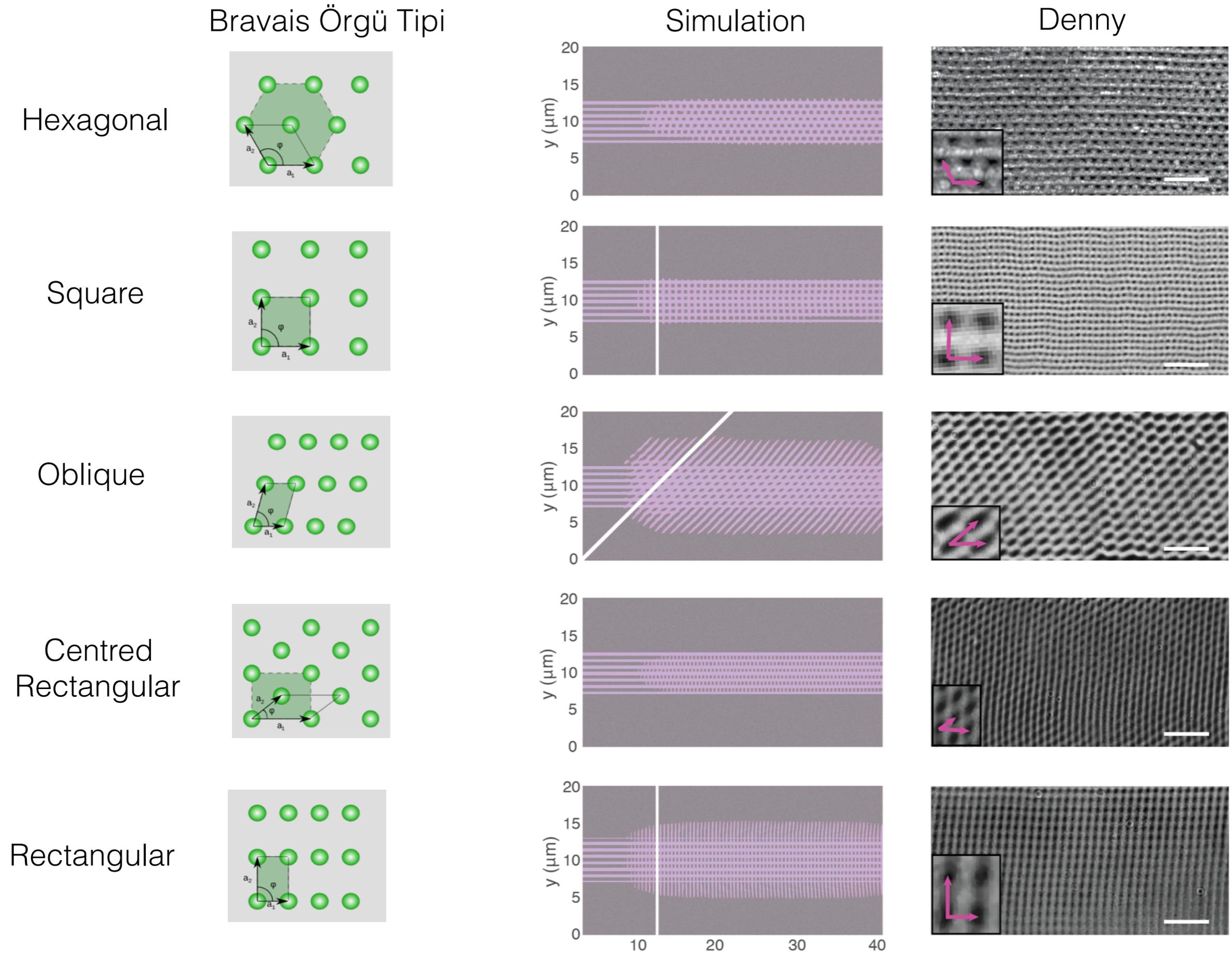
$$\Delta S < 0$$



Structured field noise turned on



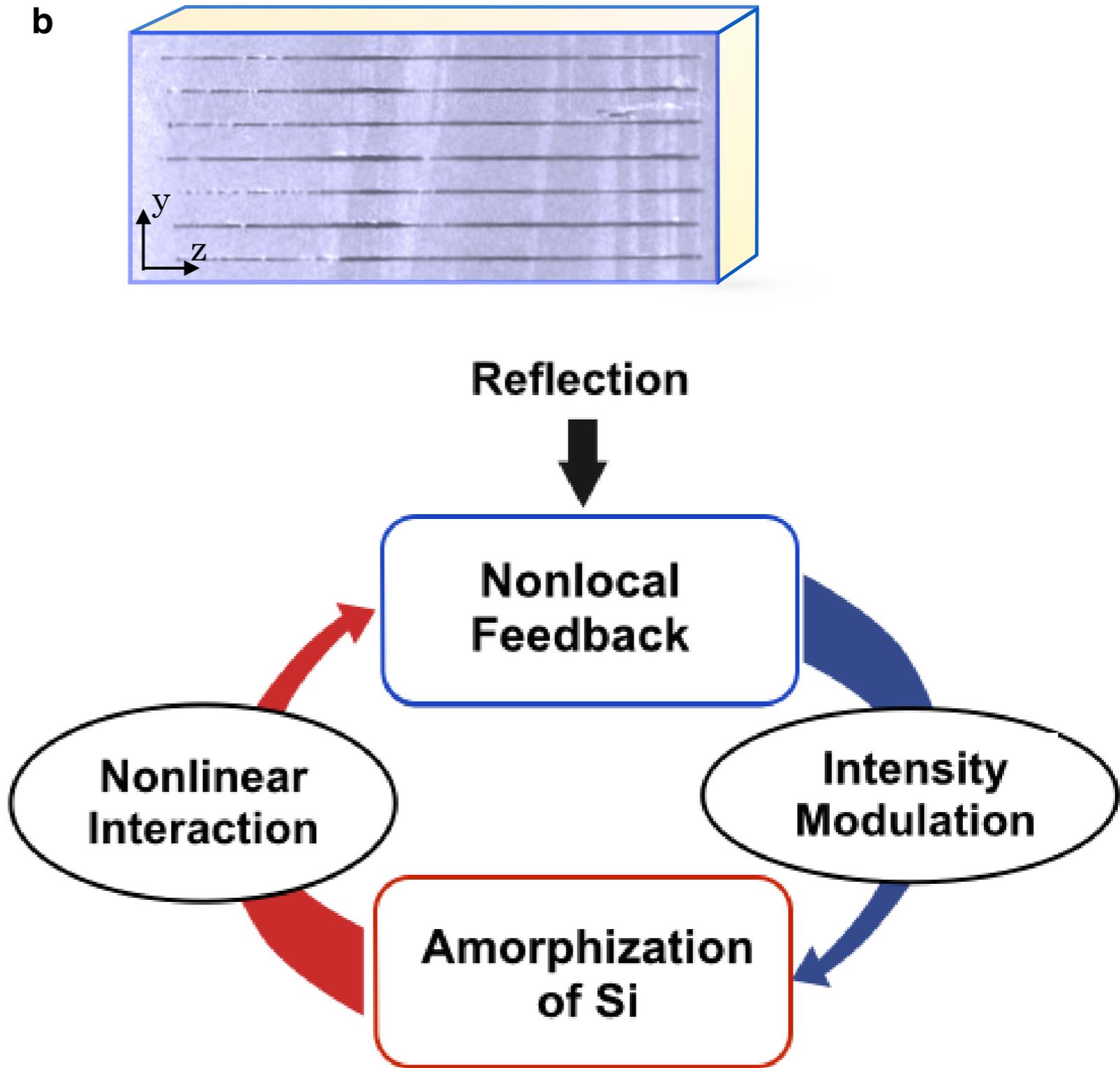
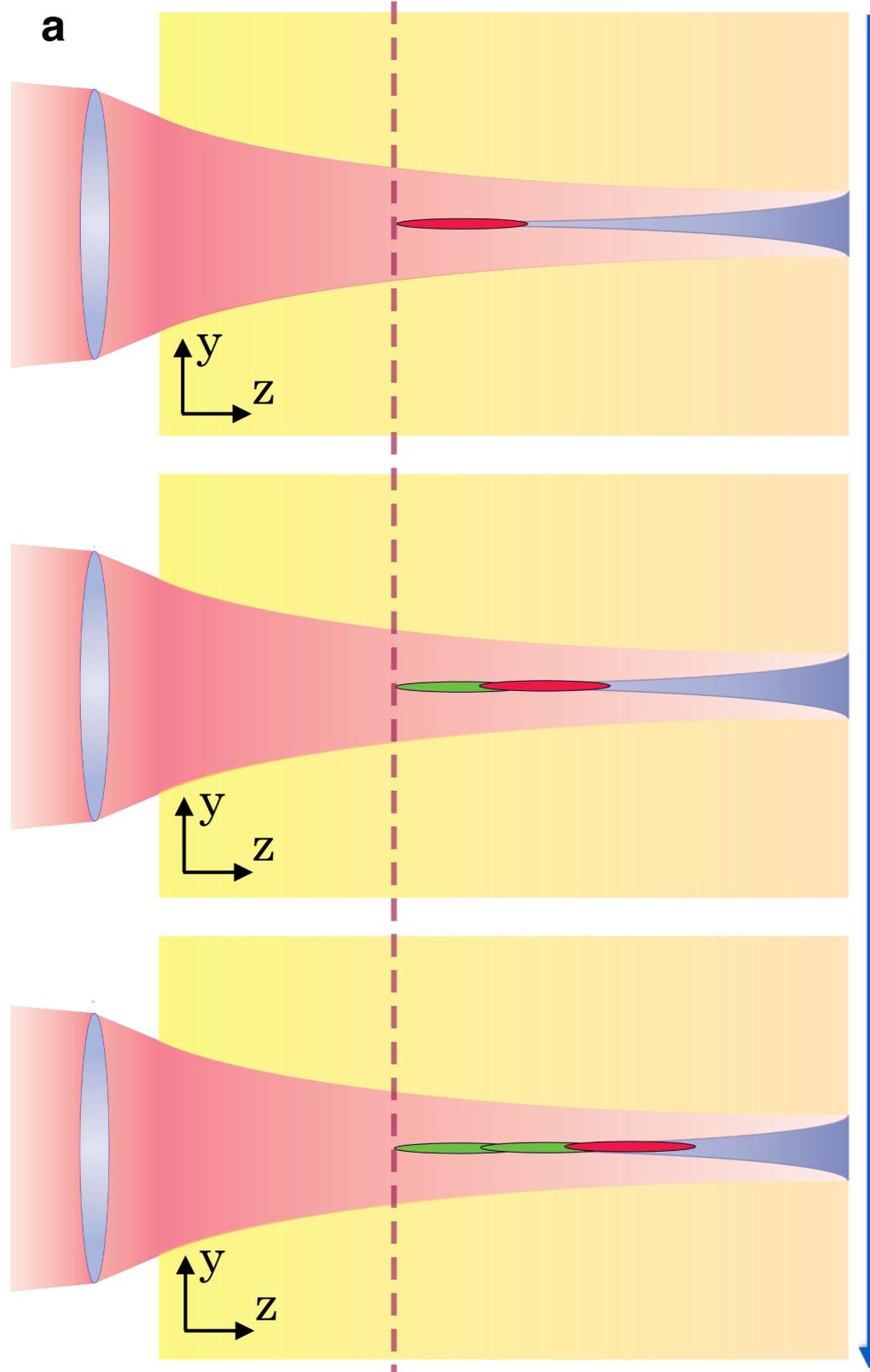
# Tüm Bravais örgülerini yaptık



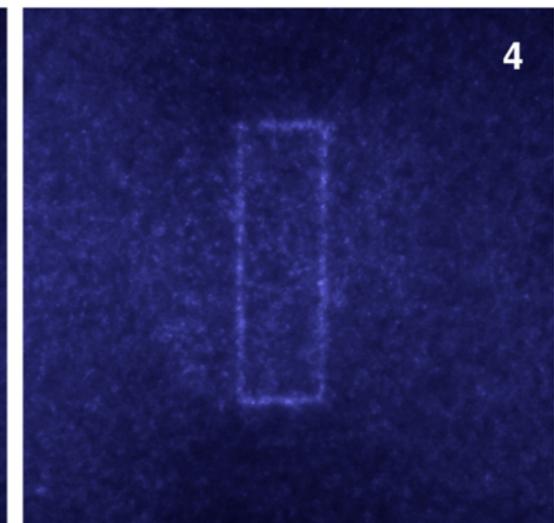
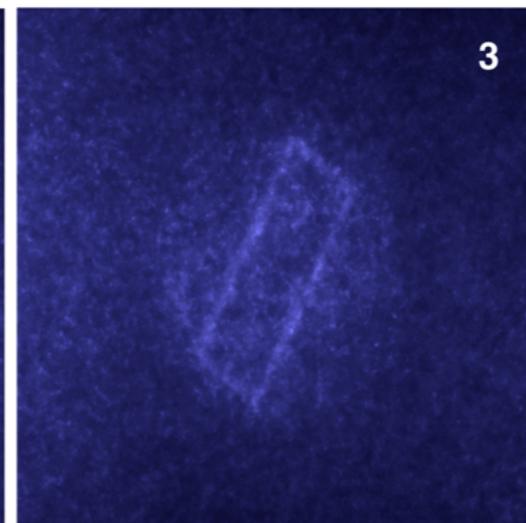
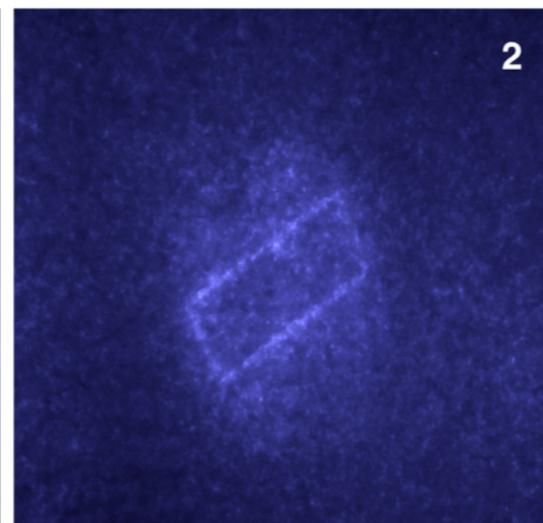
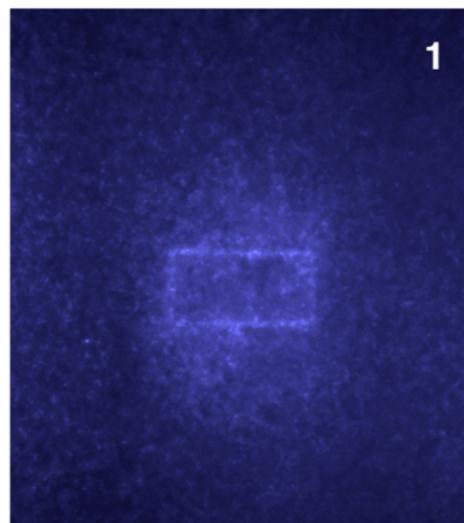
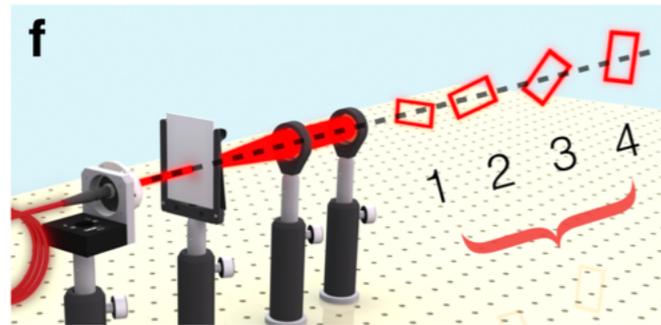
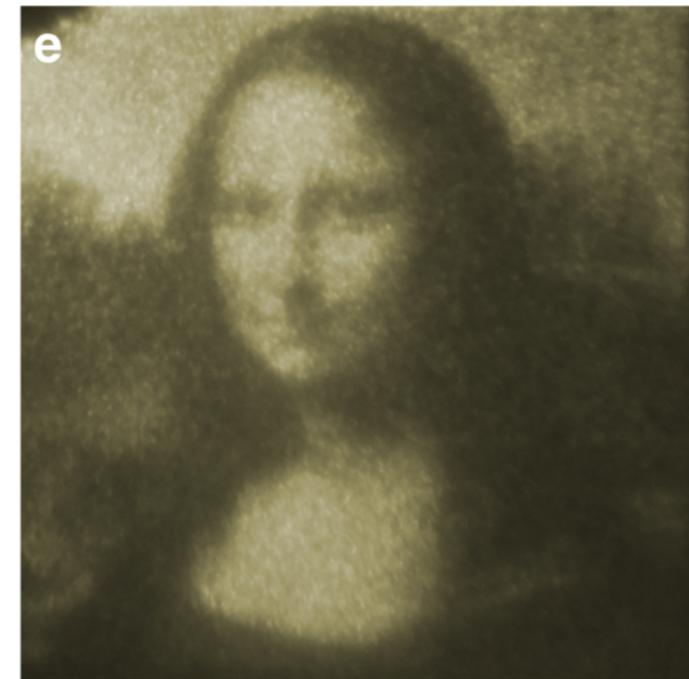
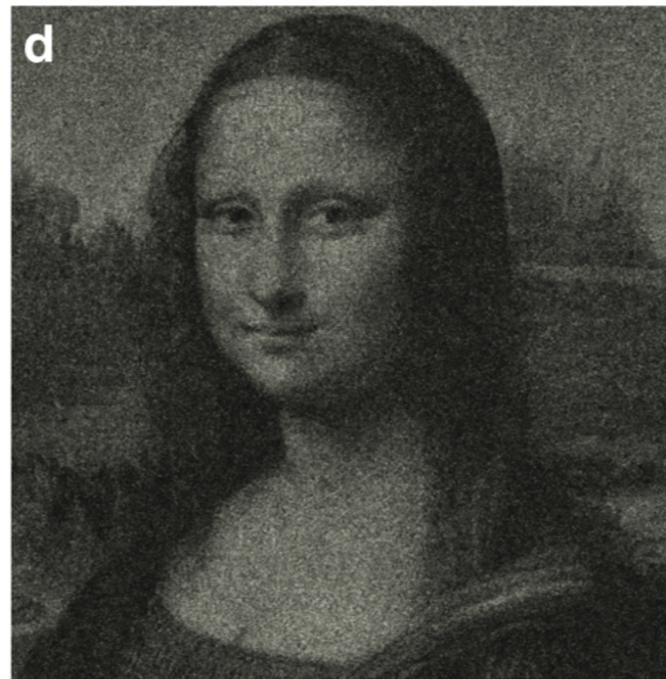
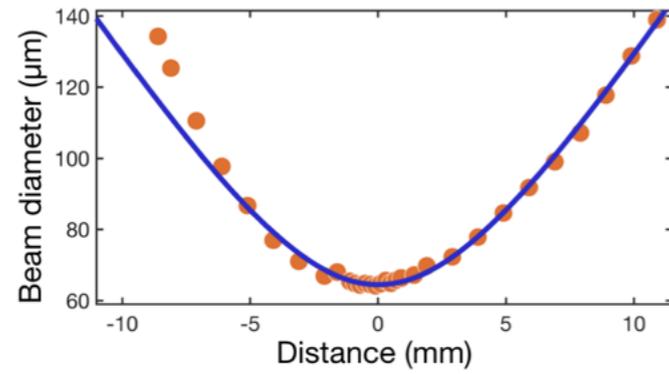
**Nonlinear Laser Lithography:**

**Silisyum içinde 3B kendiliğinden organize yapılar**

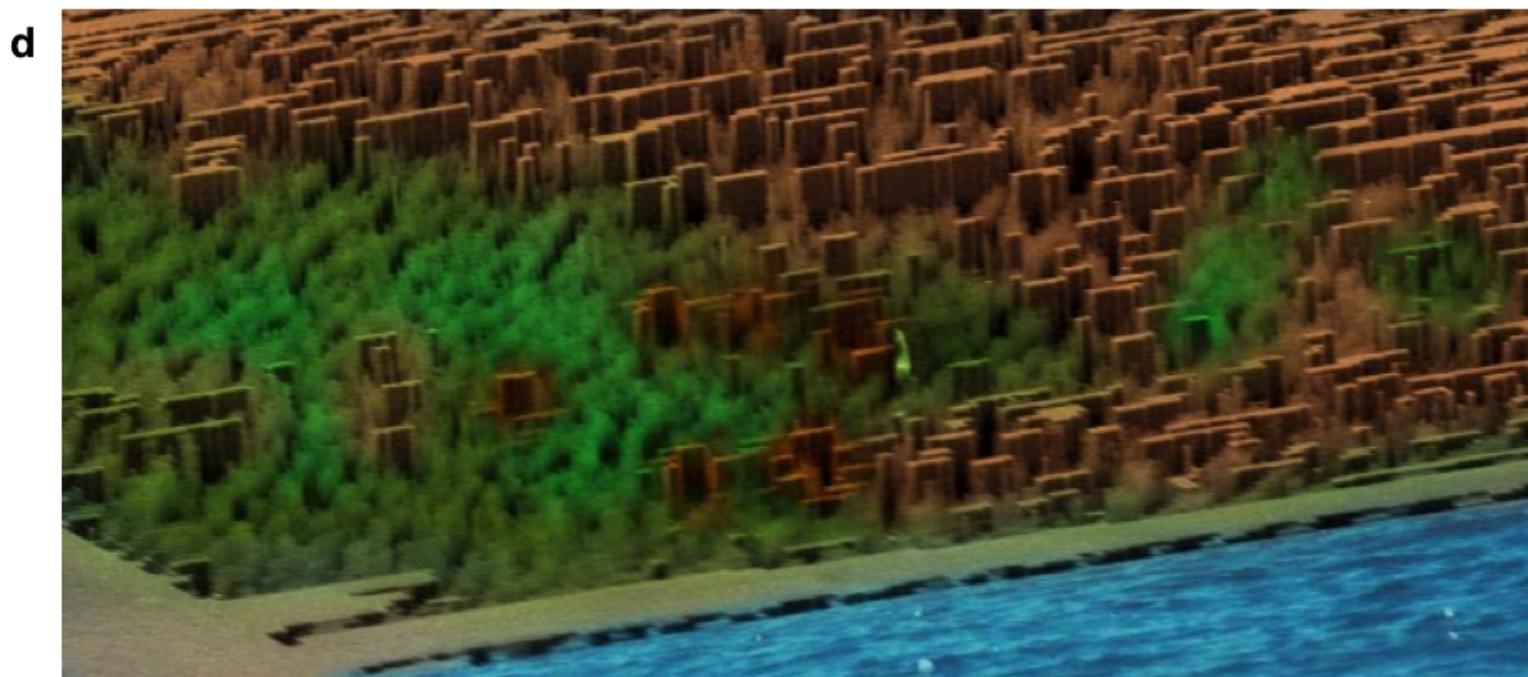
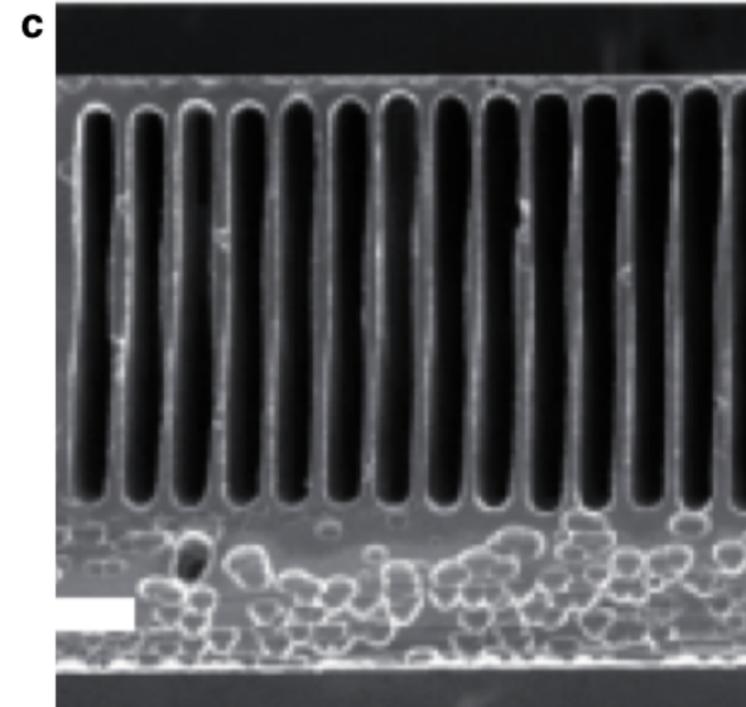
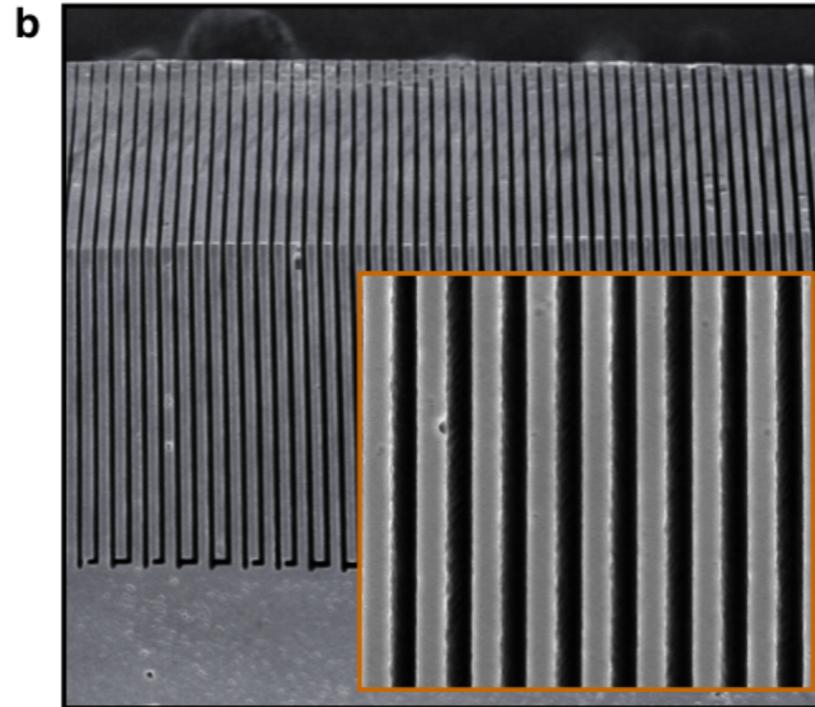
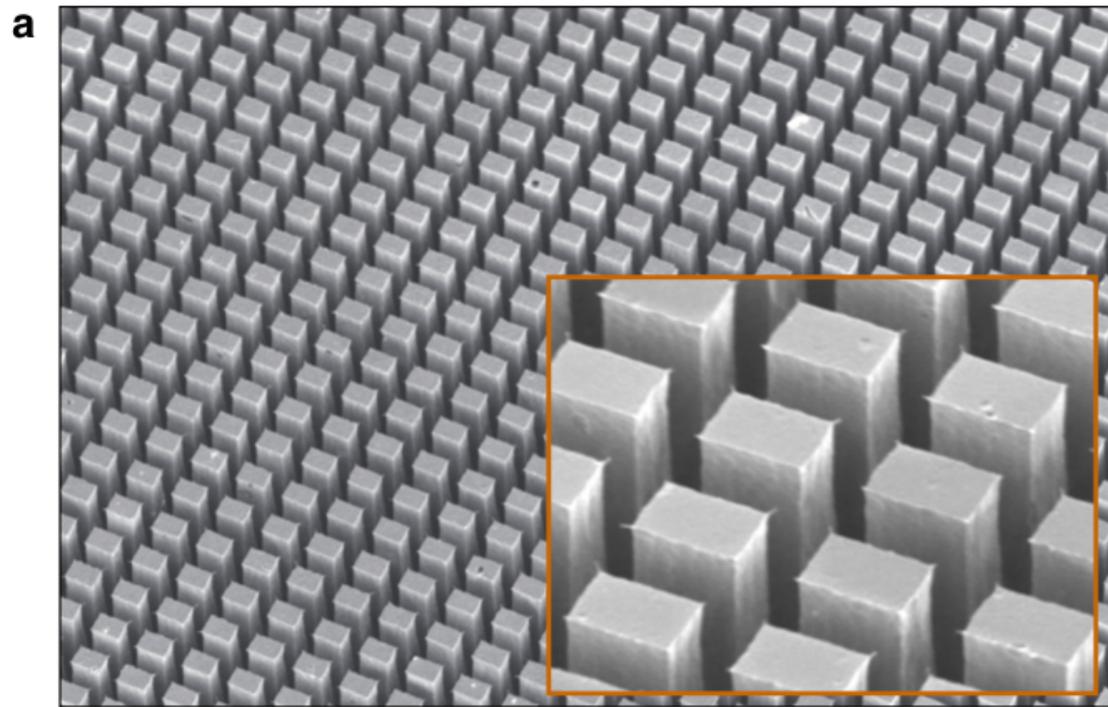
# Si içinde 3B yapı oluşumu



# Gömülü hologramlar



# 3B şekillendirme



**Kendiliğinden kurulan bir nanomalzeme**

# 3B stokastik yapının kuramsal tasarımı

$p_1$  : Si concentration

$p_2$  : “stickiness” of Si atoms to Si atoms

$p_3$  : diffusion, thereby the lateral growth tendency

j=N	i=1	i=2	i=3	...	i=M
⋮					
j=2					
j=1	$P_0$	$P_0$	$P_0$	$P_0$	$P_0$
j=0	1	1	1	1	1

$$P(i, j) = P_0 + I$$

$I(i, j) = 0$  or  $1$ ; where  $0$  is unoccupied or  $\text{SiO}_2$  and  $1$  is occupied or Si

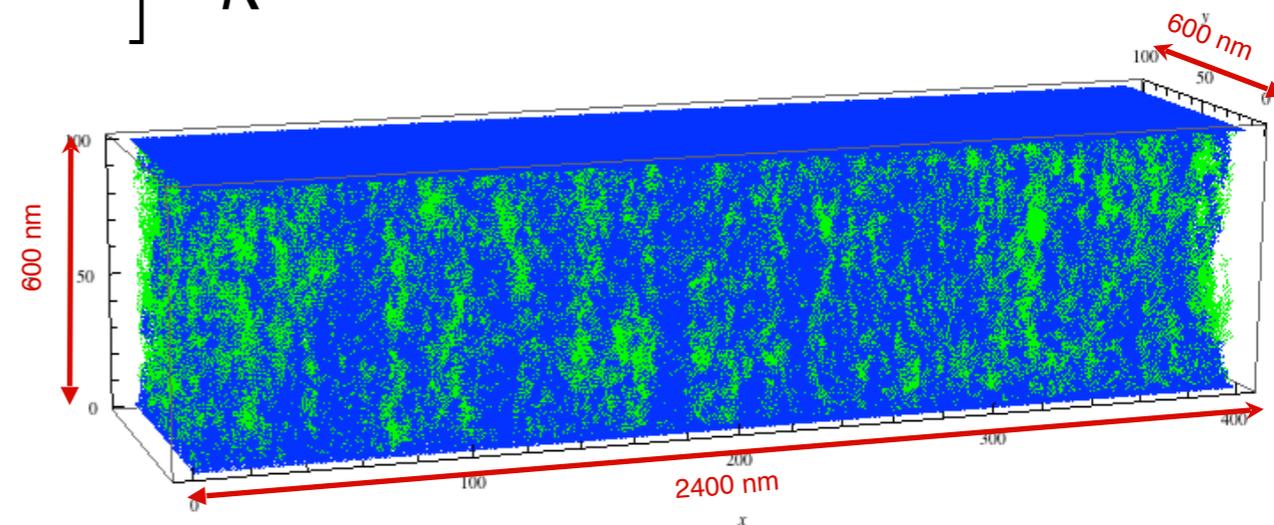
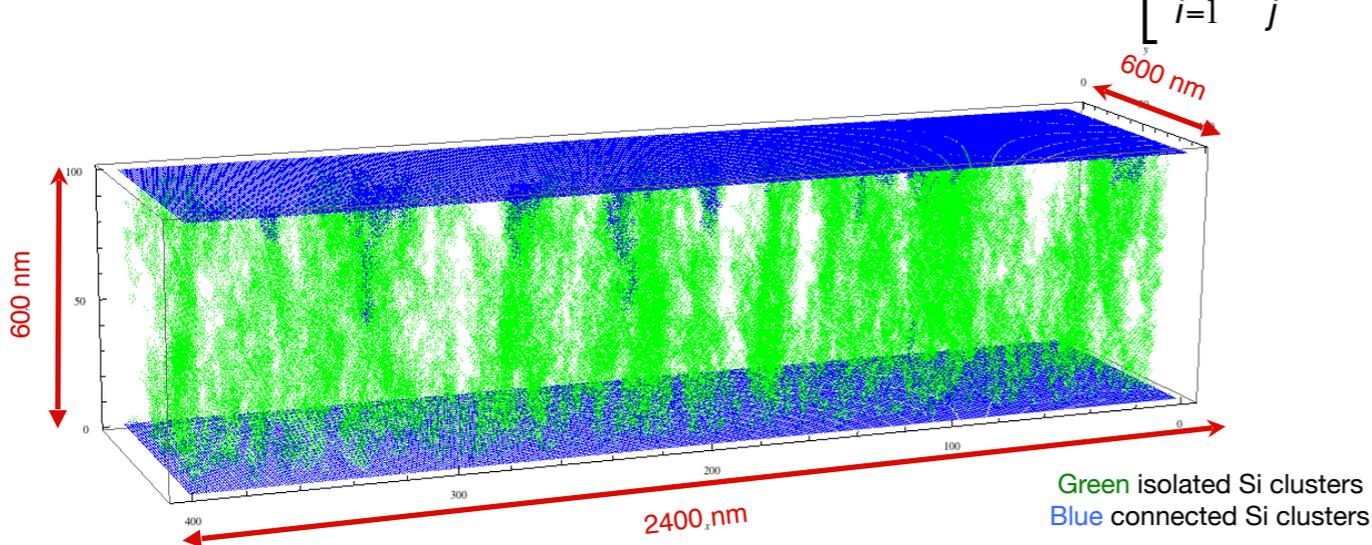
(Throw # of  $K$  particles towards  $M$  sites  $P_0 = K/M$ )

**Step 1:** Particles land with probability of  $P_0 = K/M$

**Step 2:** Particles migrate with certain probability to the neighboring sites

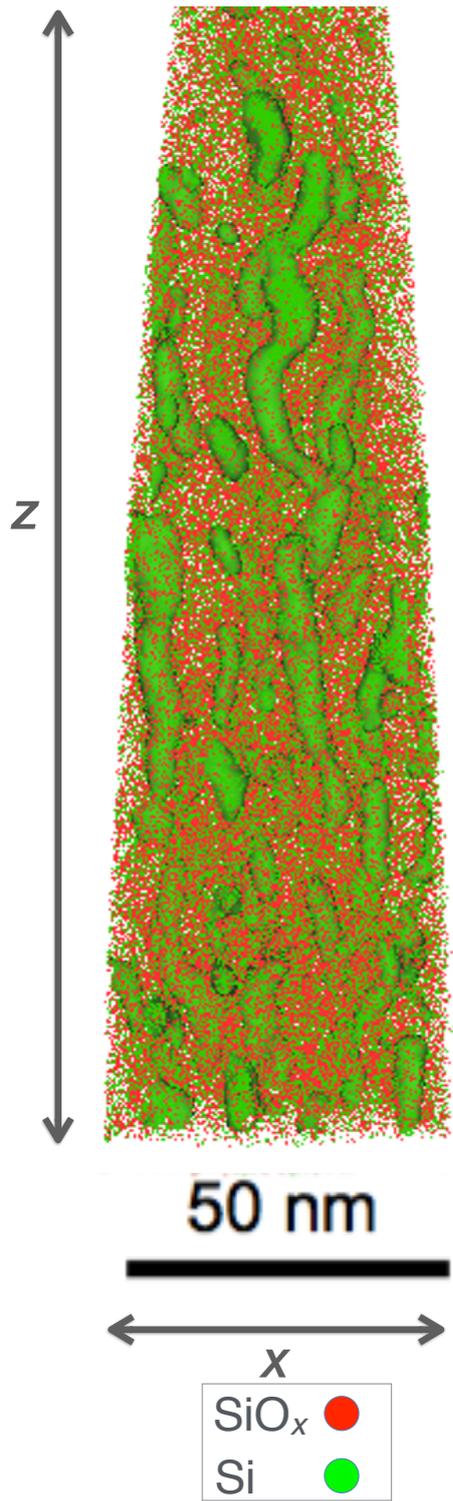
$$P(i, j, k) = \left\{ P_0 + P_1 [I(i, j, k-1)] + P_2 [I(i-1, j, k-1) + I(i+1, j, k-1) + I(i, j-1, k-1) + I(i, j+1, k-1)] \right\}$$

$$\left[ \sum_{i=1}^M \sum_{j=1}^N P(i, j, k) \right] \cdot \frac{M \cdot N}{K}$$

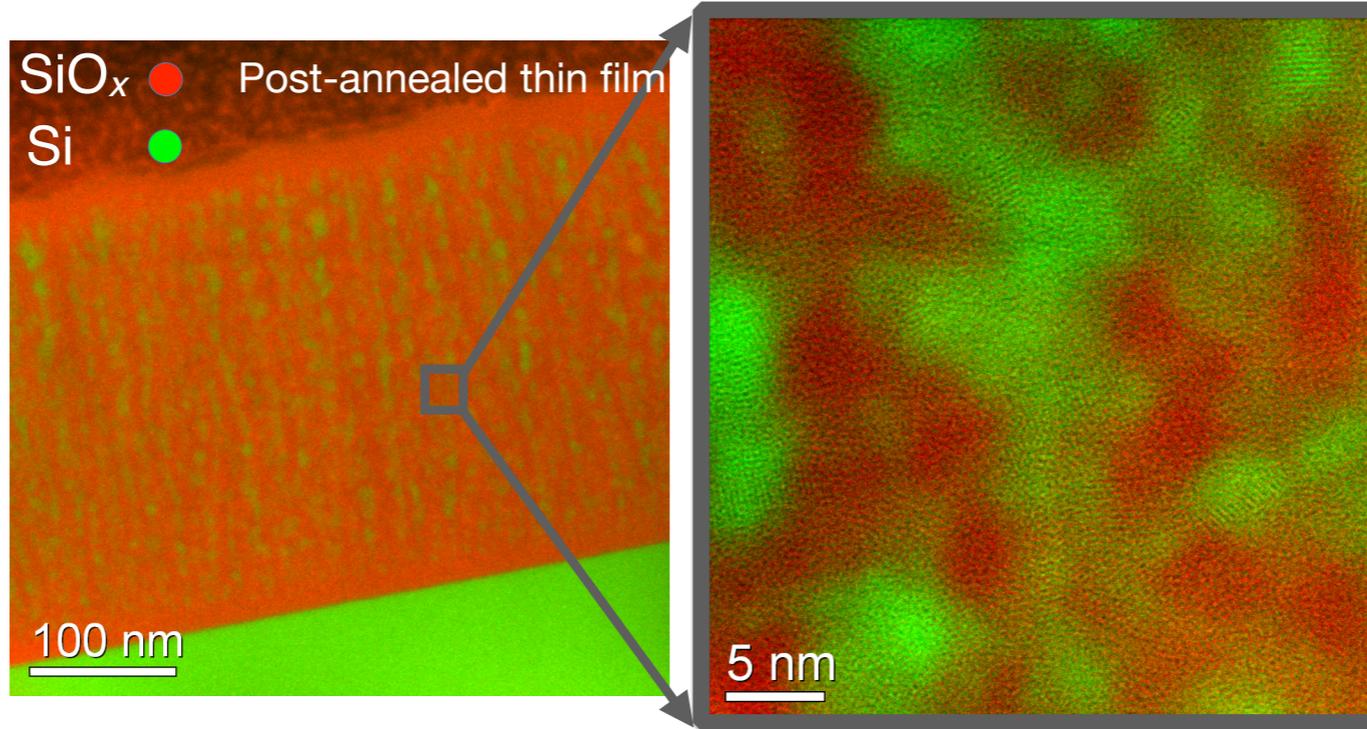


# 3B yapının deneysel karakterizasyonu

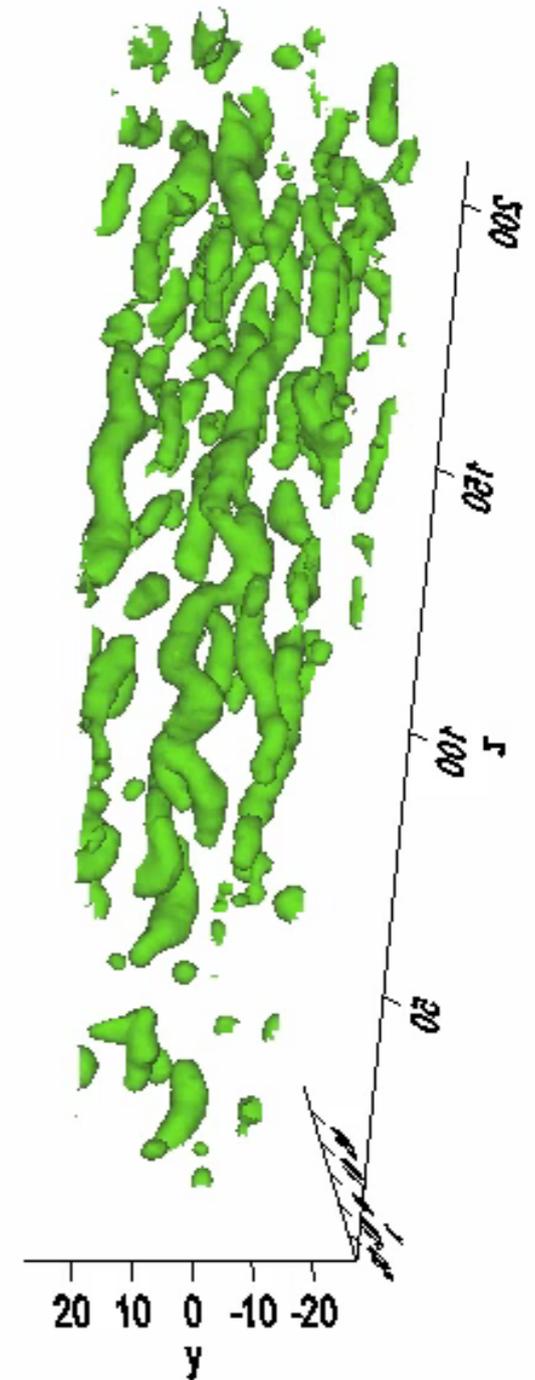
**a** APT imaging



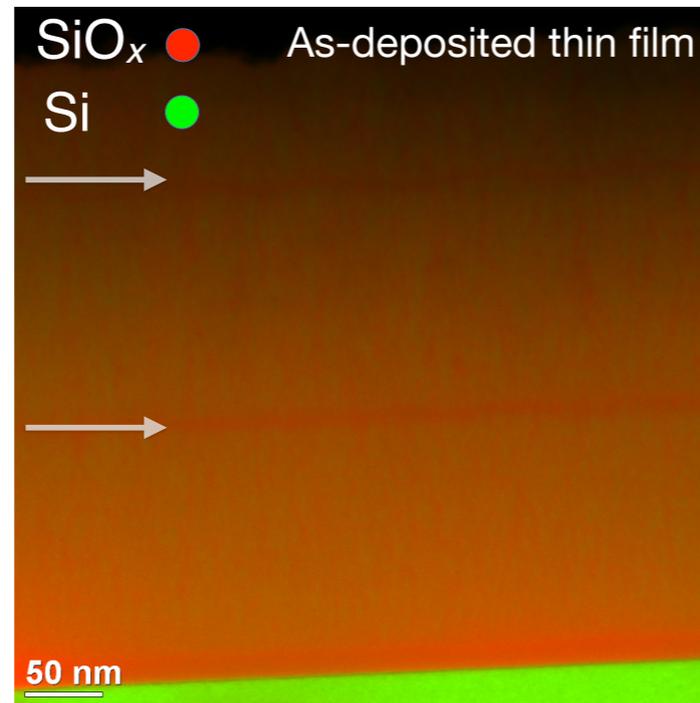
**b** EFTEM imaging



**network**



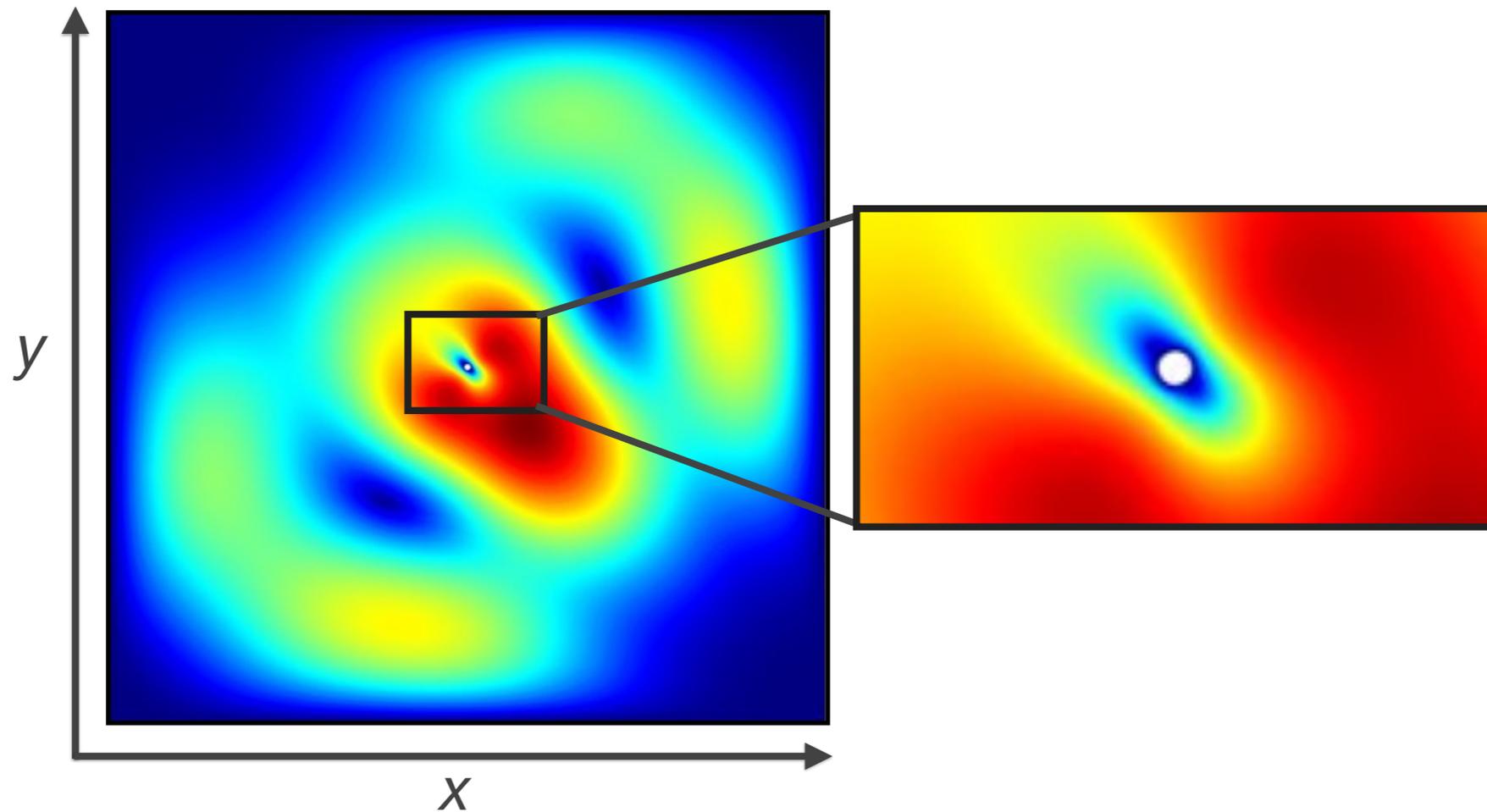
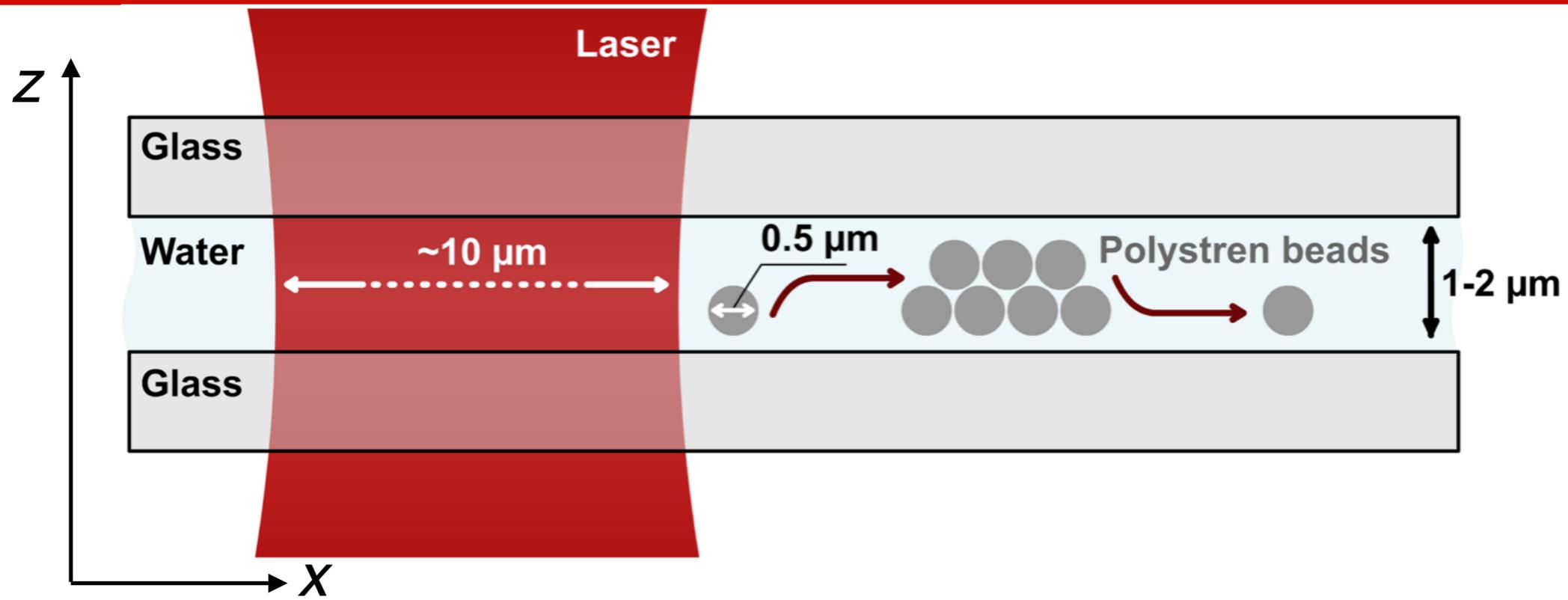
**c**



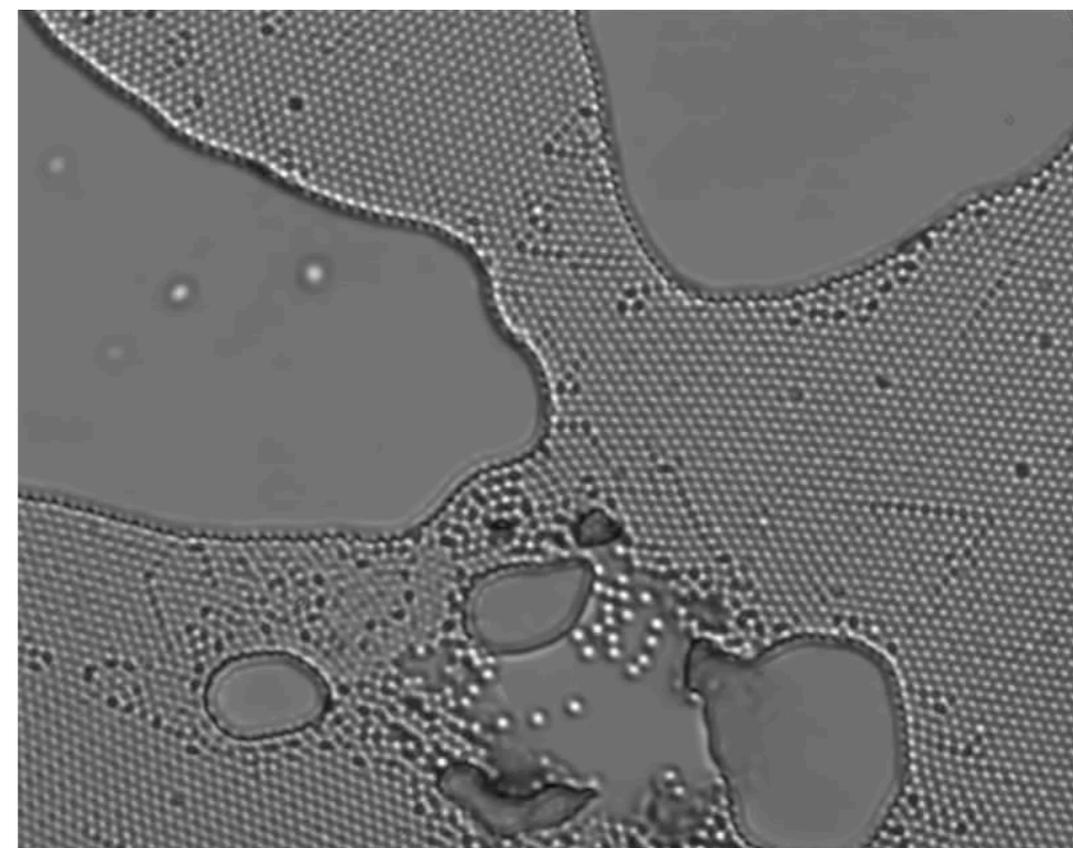
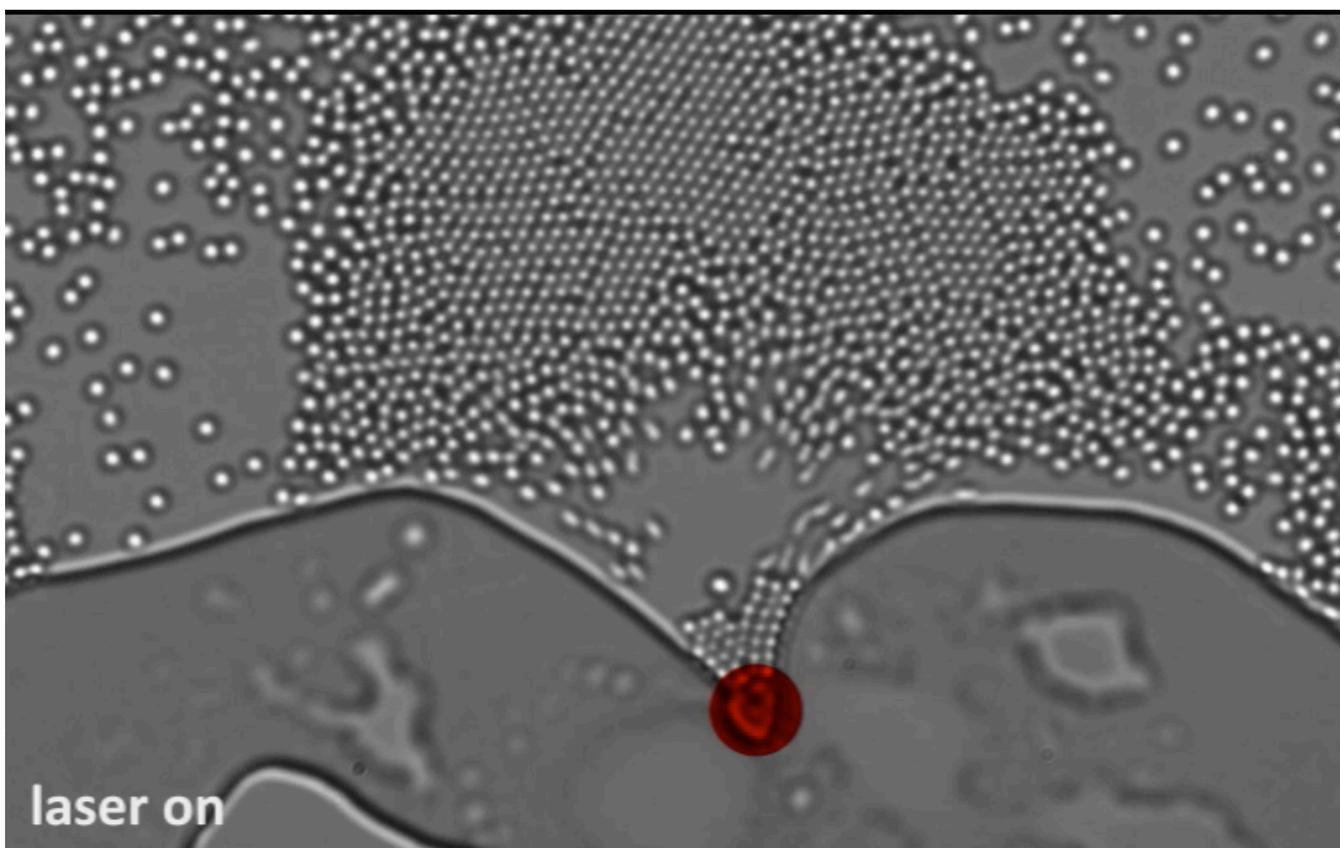
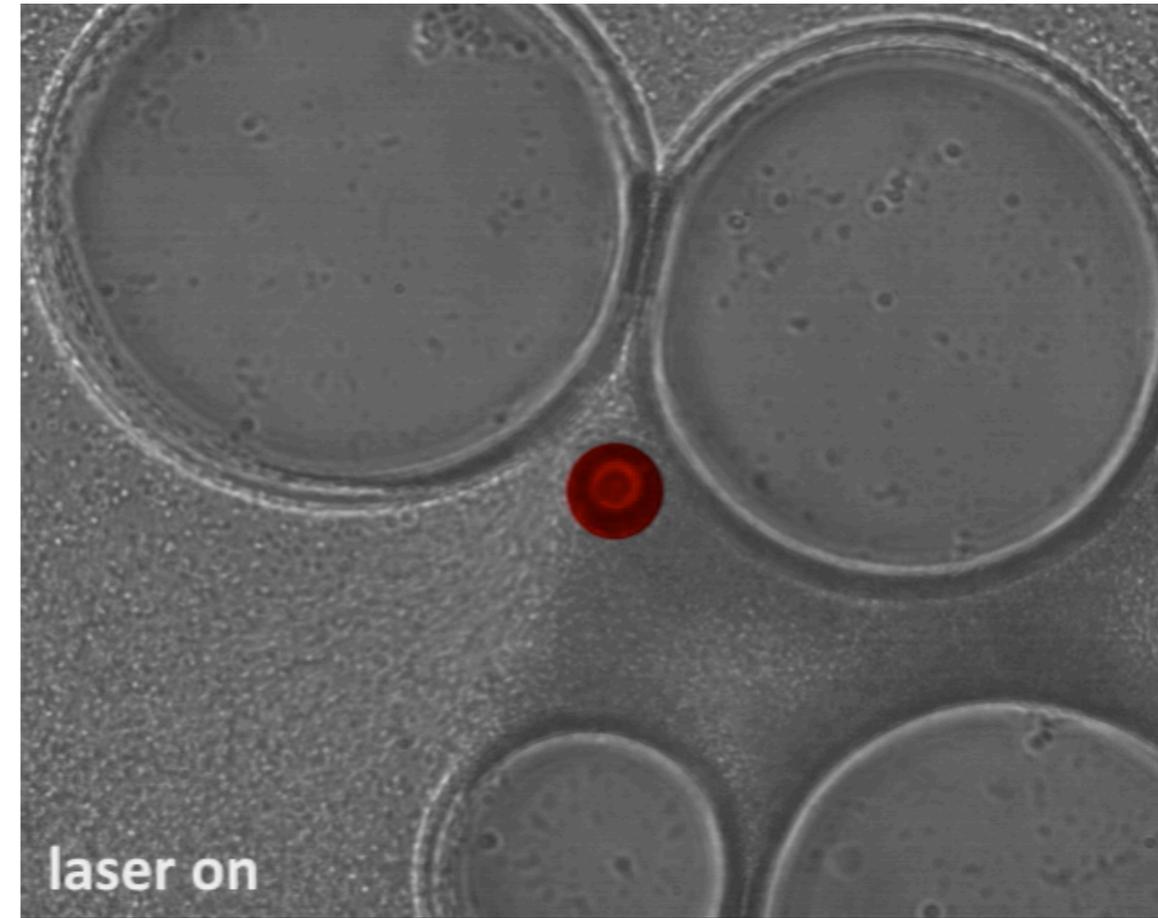
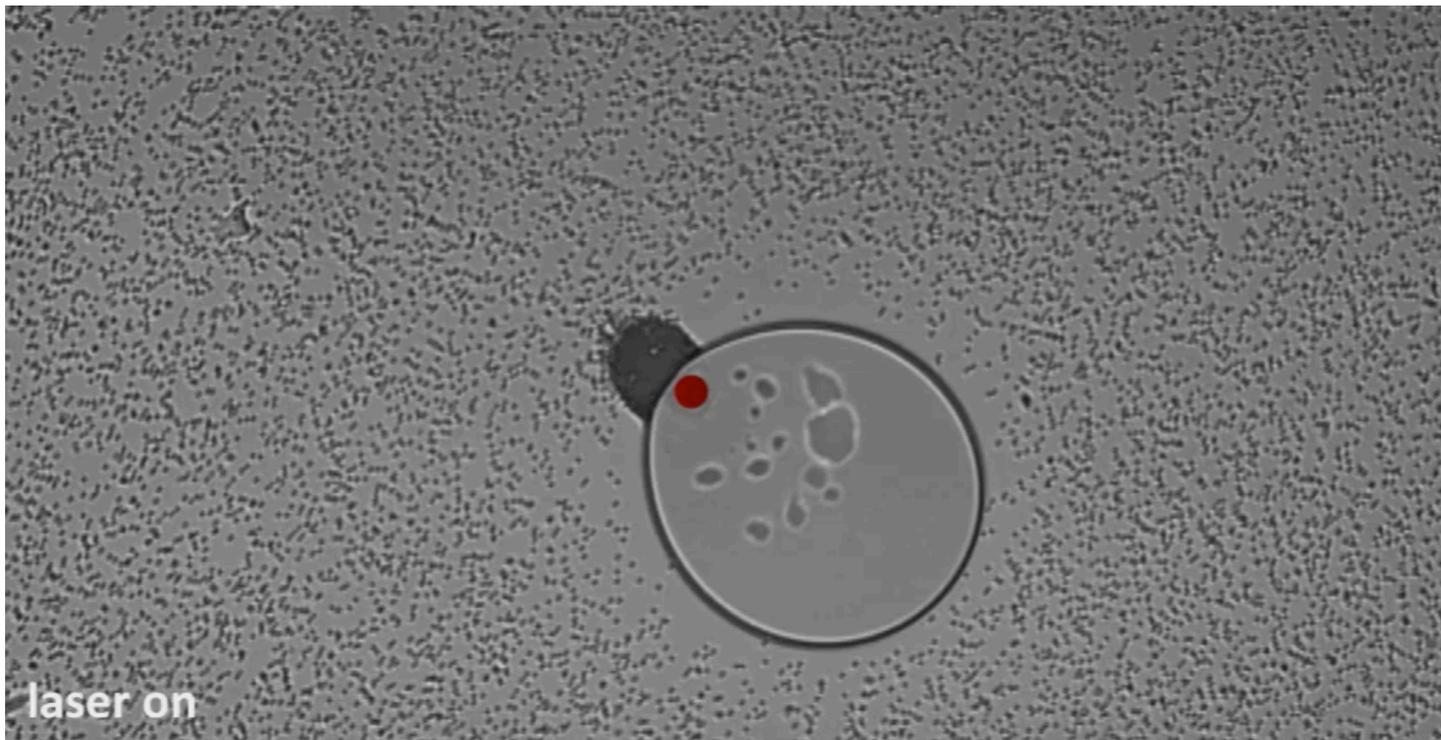
Atom Probe Tomography and EFTEM images: **Si (green)** and the  **$\text{SiO}_x$  (red)**

**Kendiliğinden-kurulan  
canlı-gibi-özellikler gösteren  
nanoyapılar**

# Lazer soğurumu ile Marangoni akışı

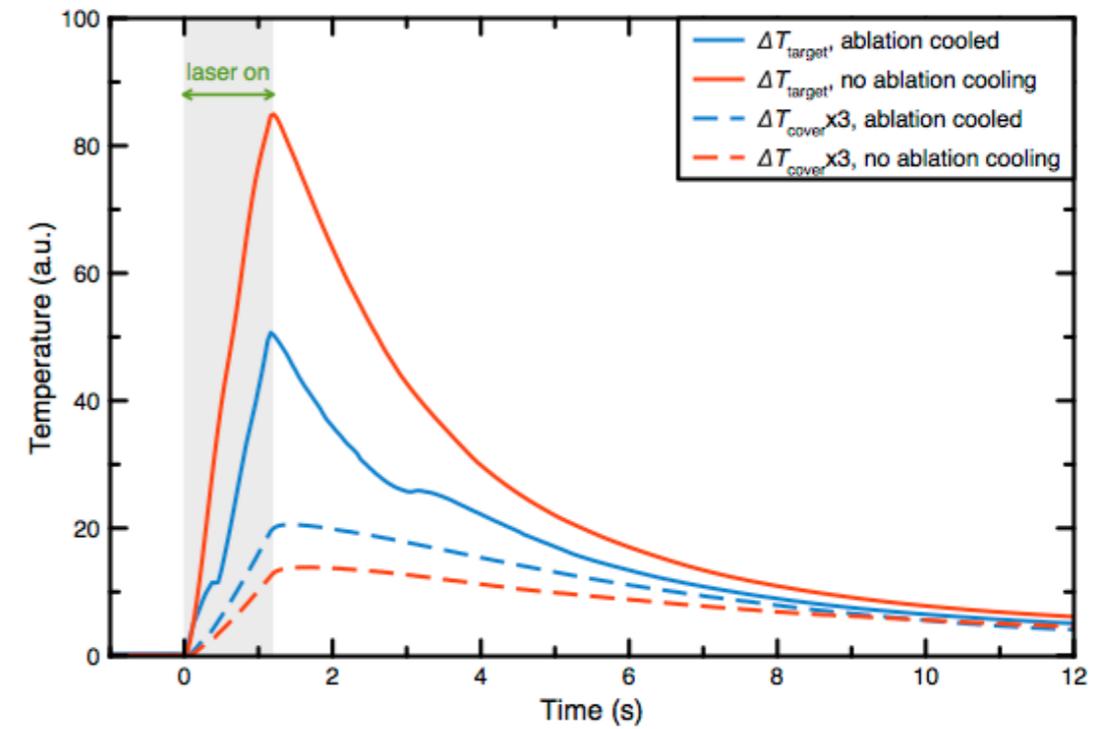
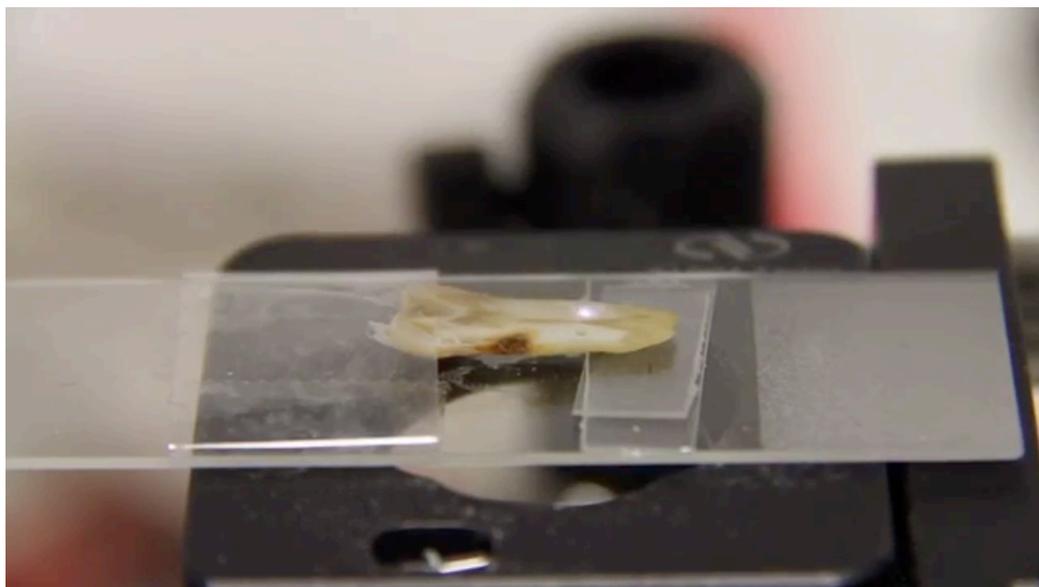
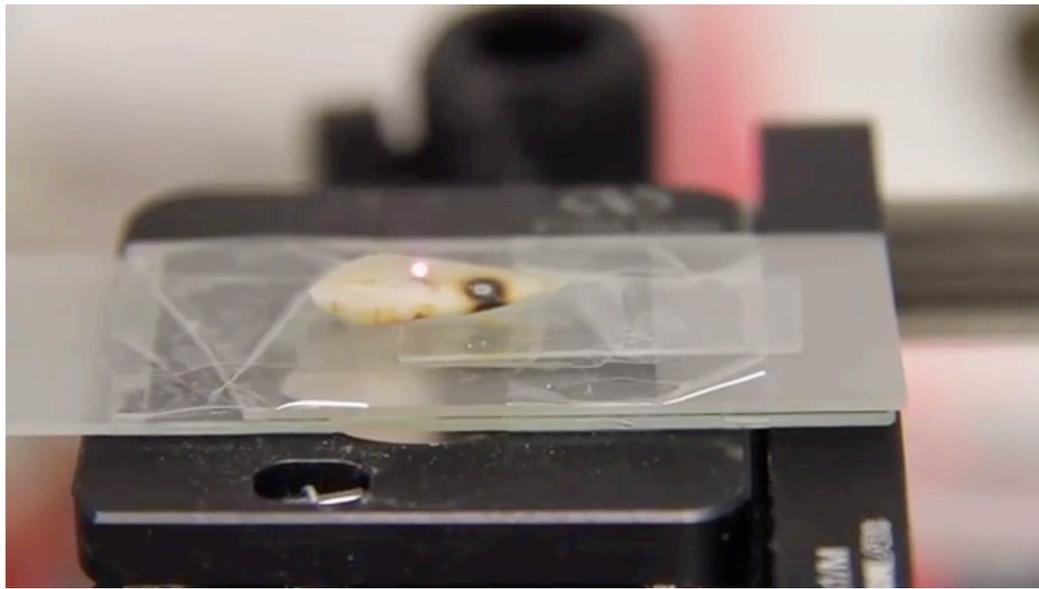
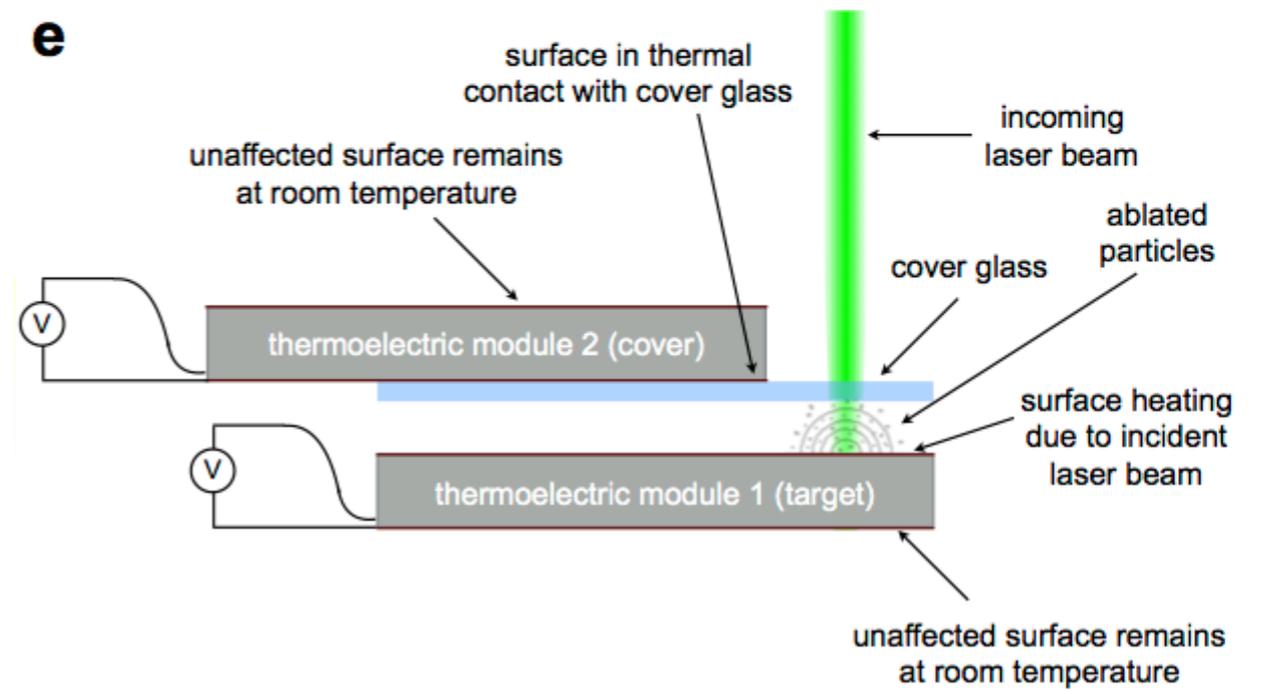
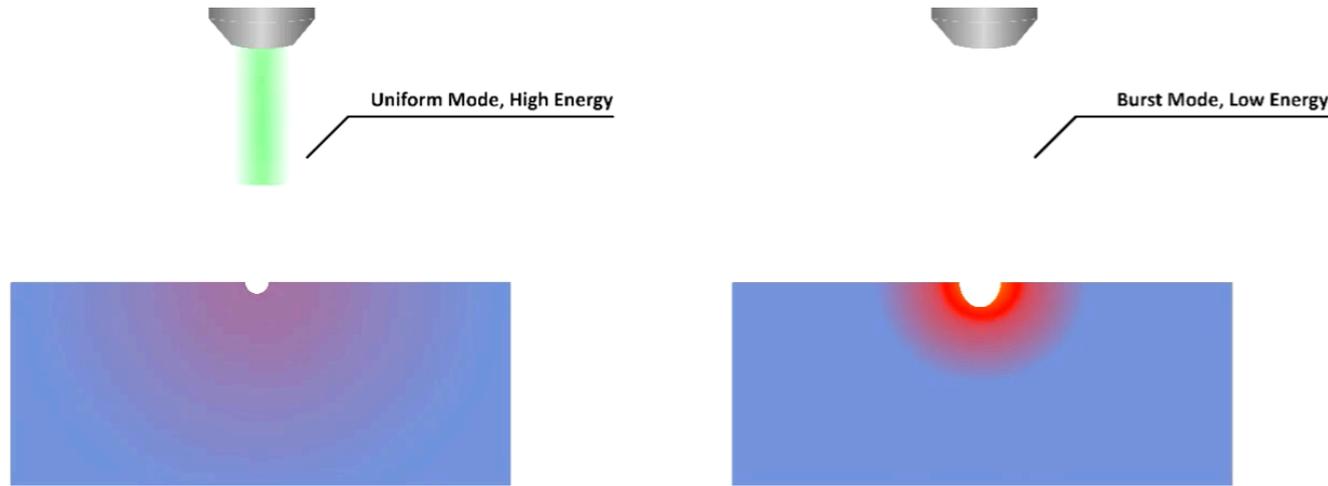


# Nonlinear absorption of pulses creates Marangoni flow



**Ablasyon-soğutmalı lazer ile malzeme kesimi**

# Yıkımlama soğutmalı lazer malzeme kesimi



Spekülatif soru: proton terapisine uygulanabilir mi?

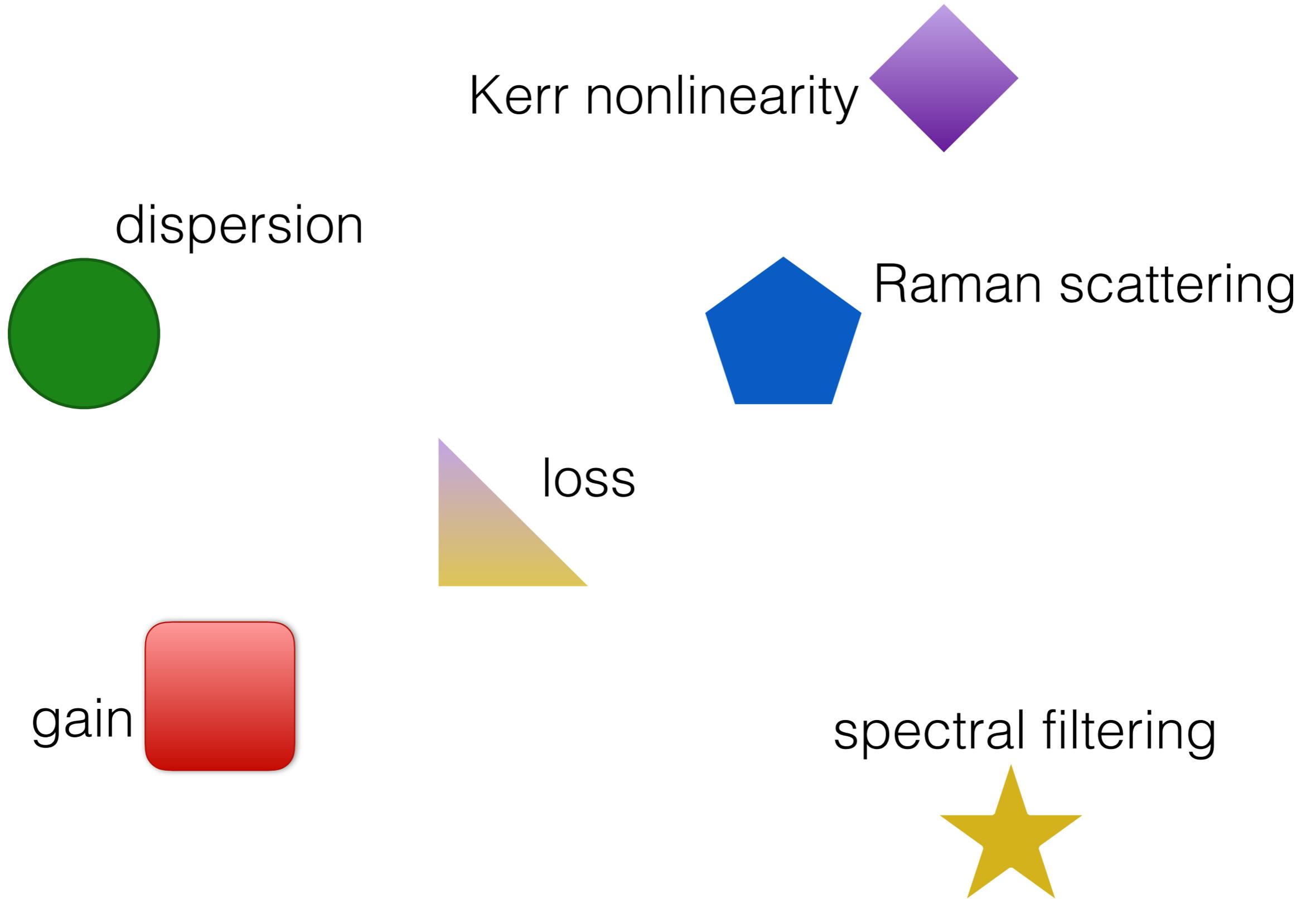
Ilday, et al., Nature'da yayınlanacak (2016)

# Kip-kilitleme/dengeden-uzak-sistemler teorisi

Genel teori yok.

Neden yok?

# Çeşitli kuvvetler etkin; tüm analitik teoriler bunları birbirine ekliyor



Ancak, süperpozisyon çalışmıyor.

Bütünü parçaların **toplamı** olarak yazamıyoruz.

Öte yandan, operatörleri **çarpabiliriz** (ucu uca ekleyebiliriz)!

# Temel operatörleri belirledik



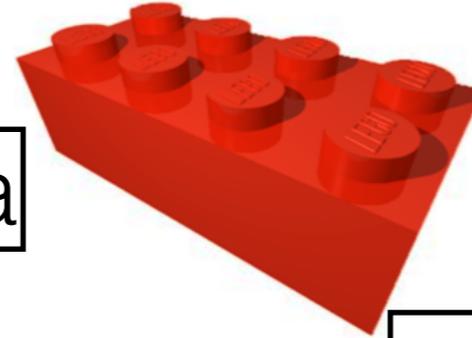
soliton

similariton (self-similar)



doğrusal olmayan zamanda sıkıştırma

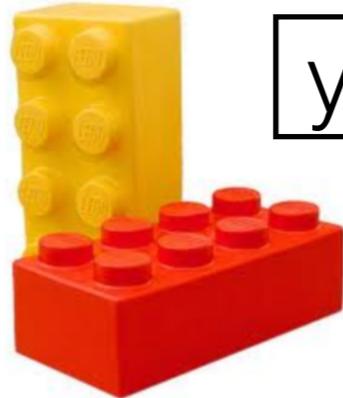
doğrusal olmayan spektral sıkıştırma



doğrusal ilerleme



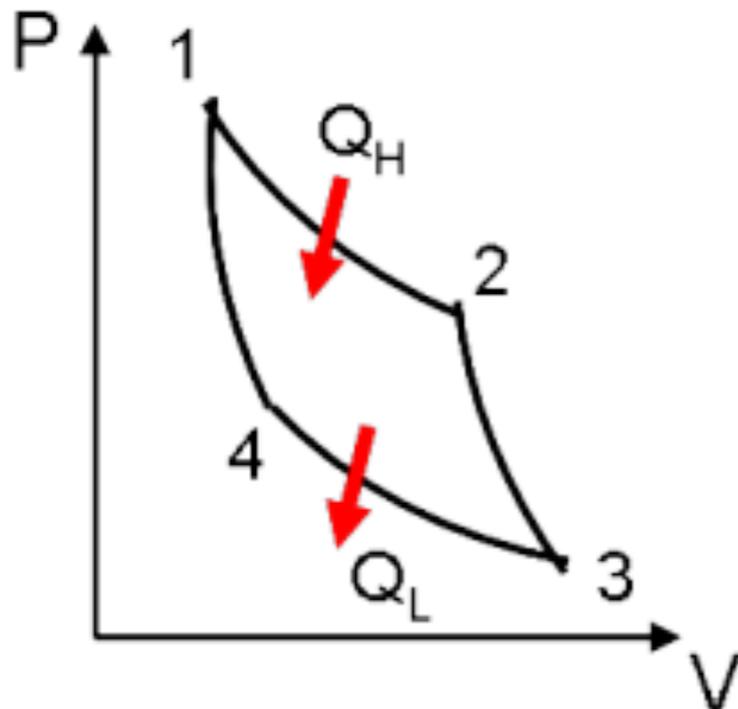
yitirgen soliton



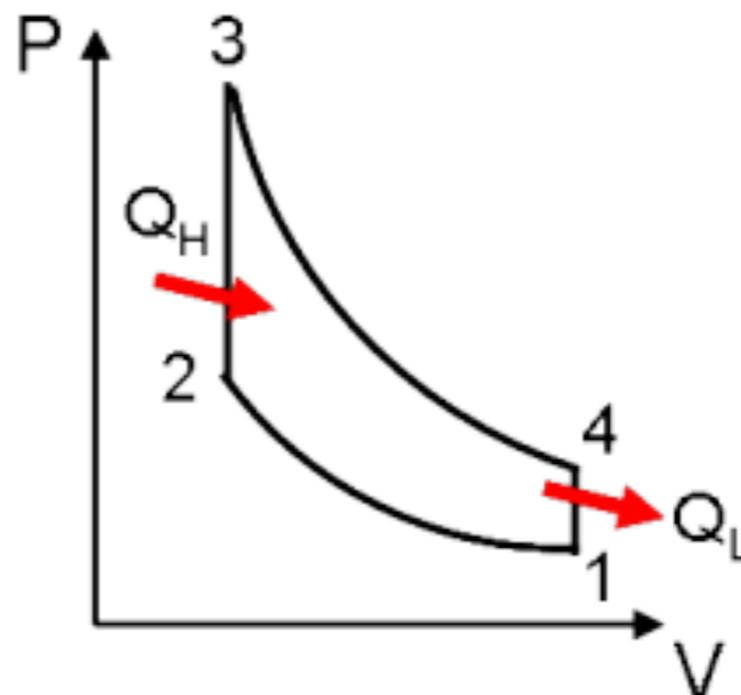
# Termodinamiğe analoji yapıyoruz...

- Consists of basic processes: *adiabatic*, *isothermal*, *isobaric*, *isochroic*
- Each cycle is a closed loop.

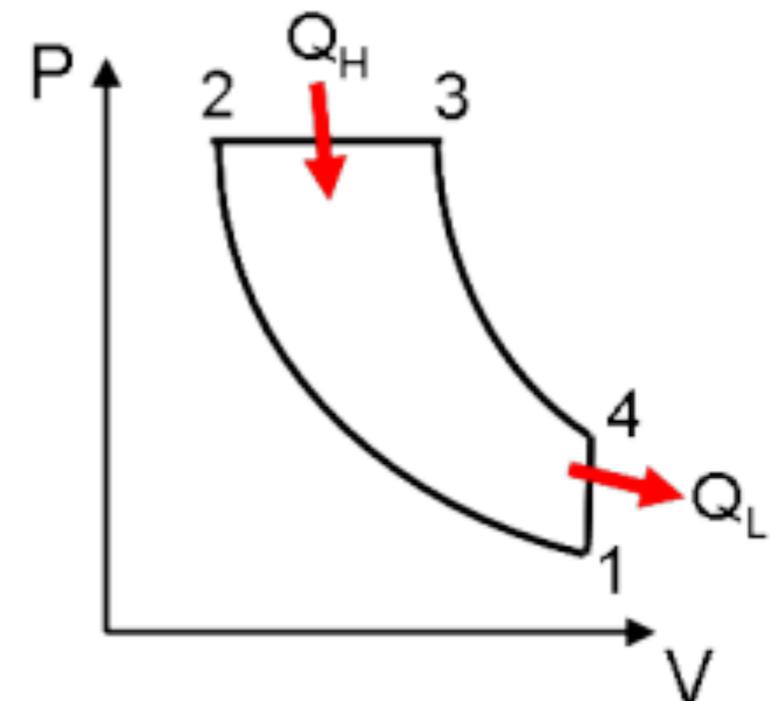
Carnot Cycle



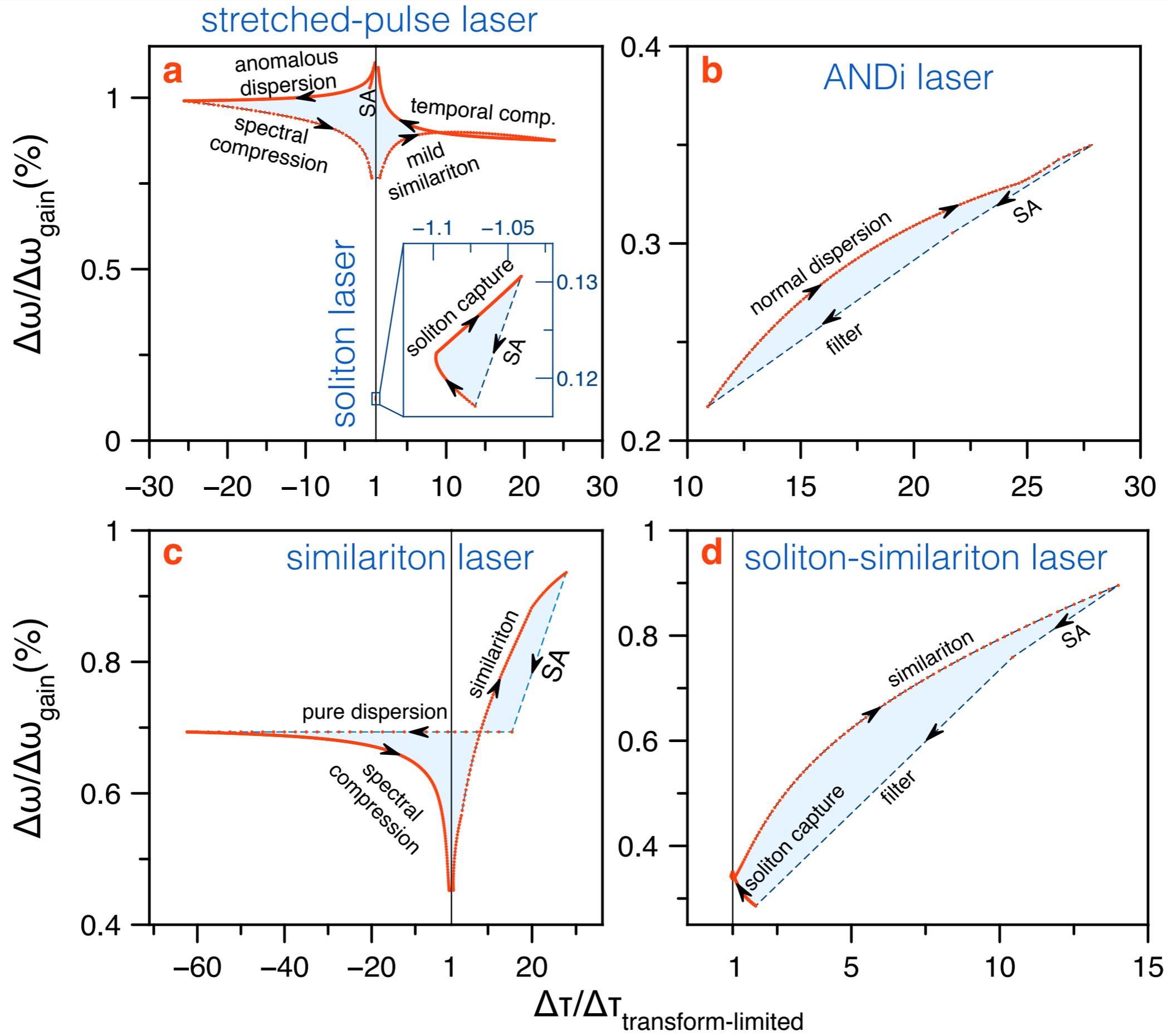
Otto Cycle



Diesel Cycle

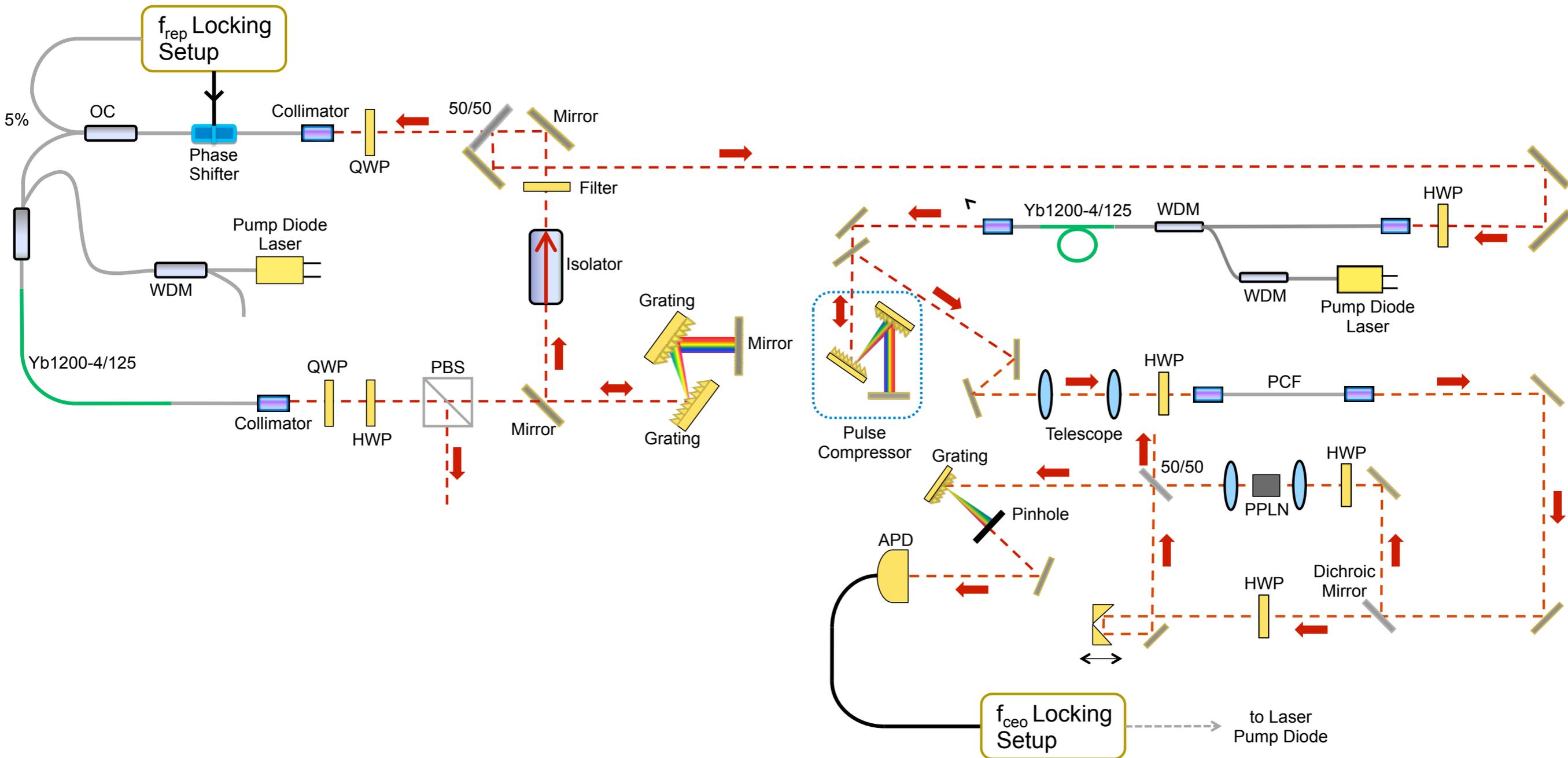


# Bu sayede lazerlerin dinamiklerini kurgulabiliyoruz

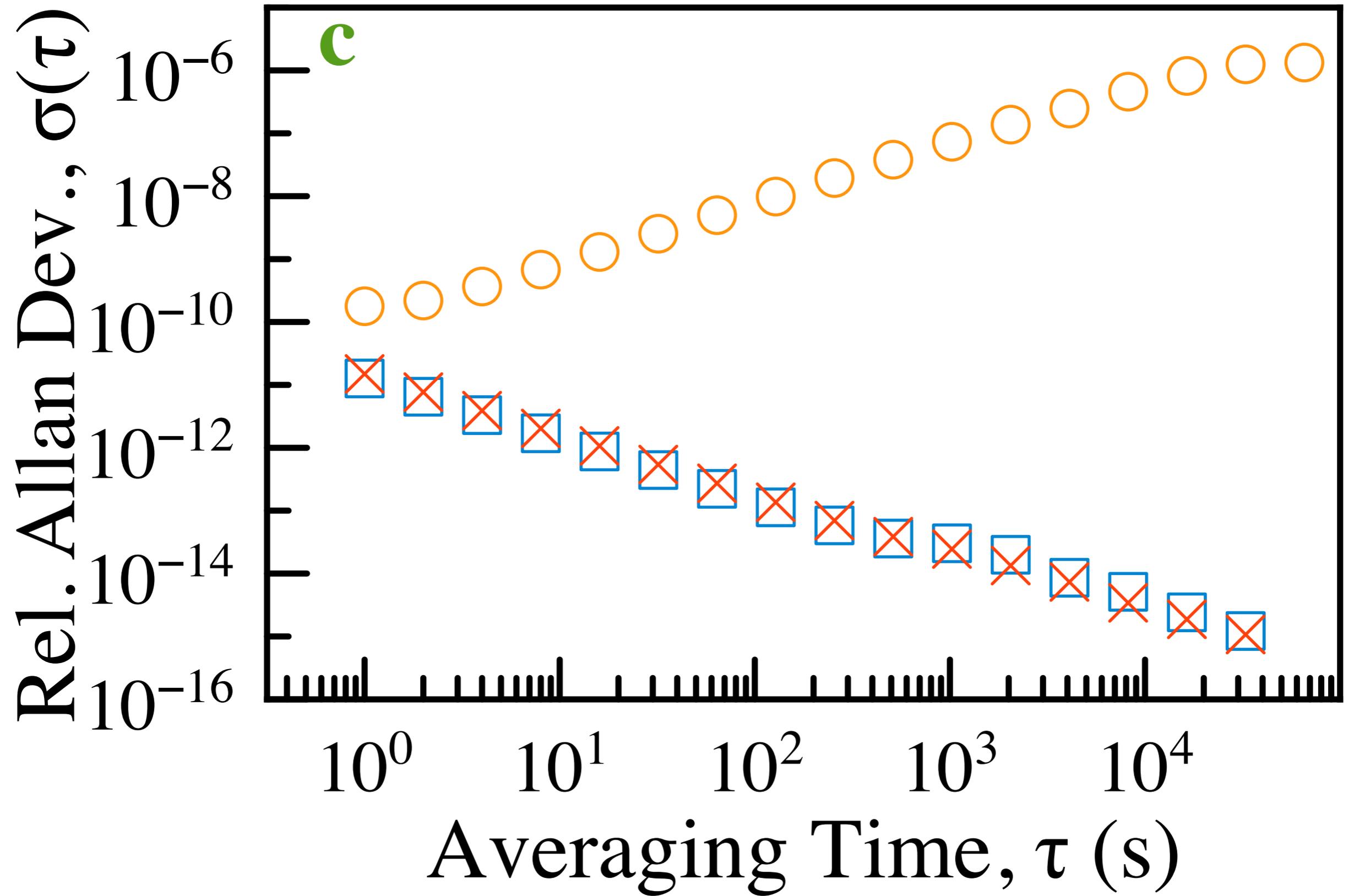


# Lazer teknolojisi

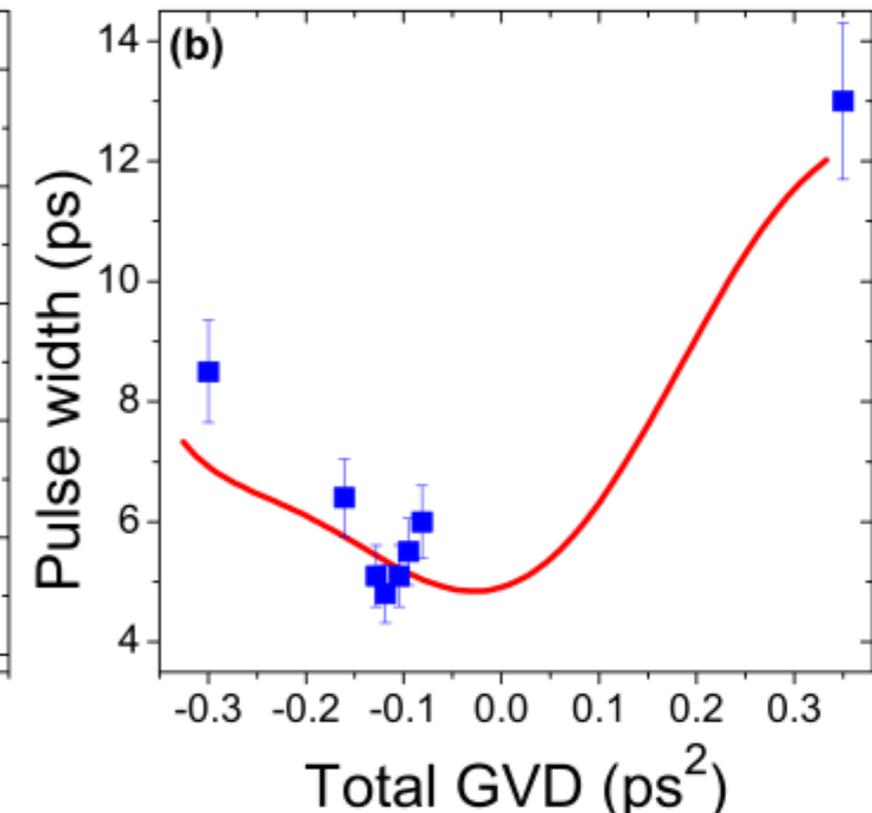
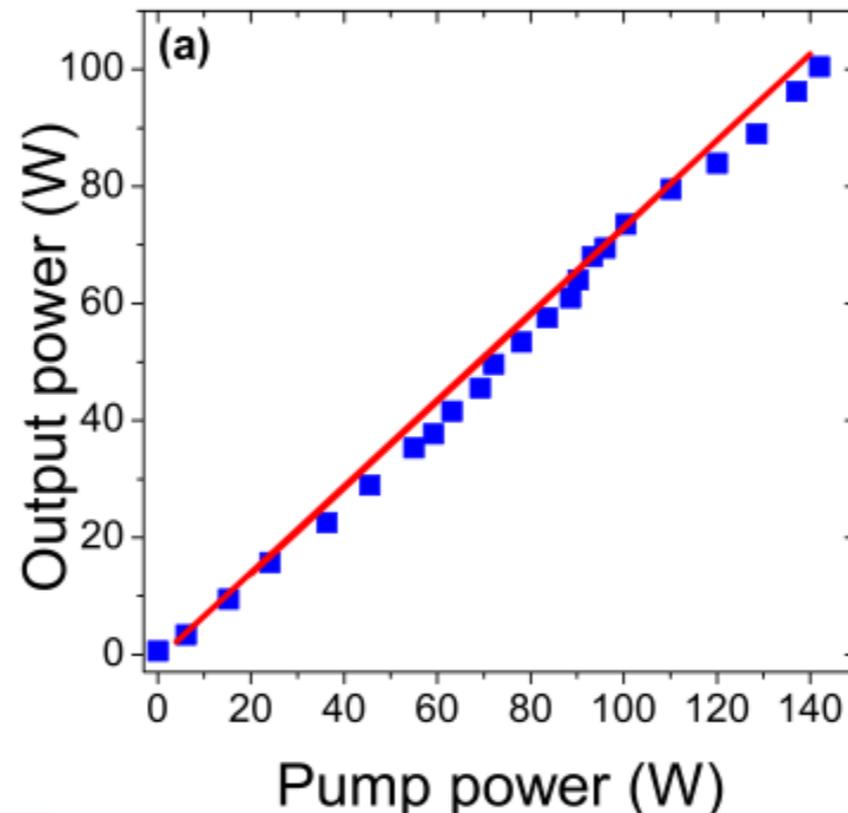
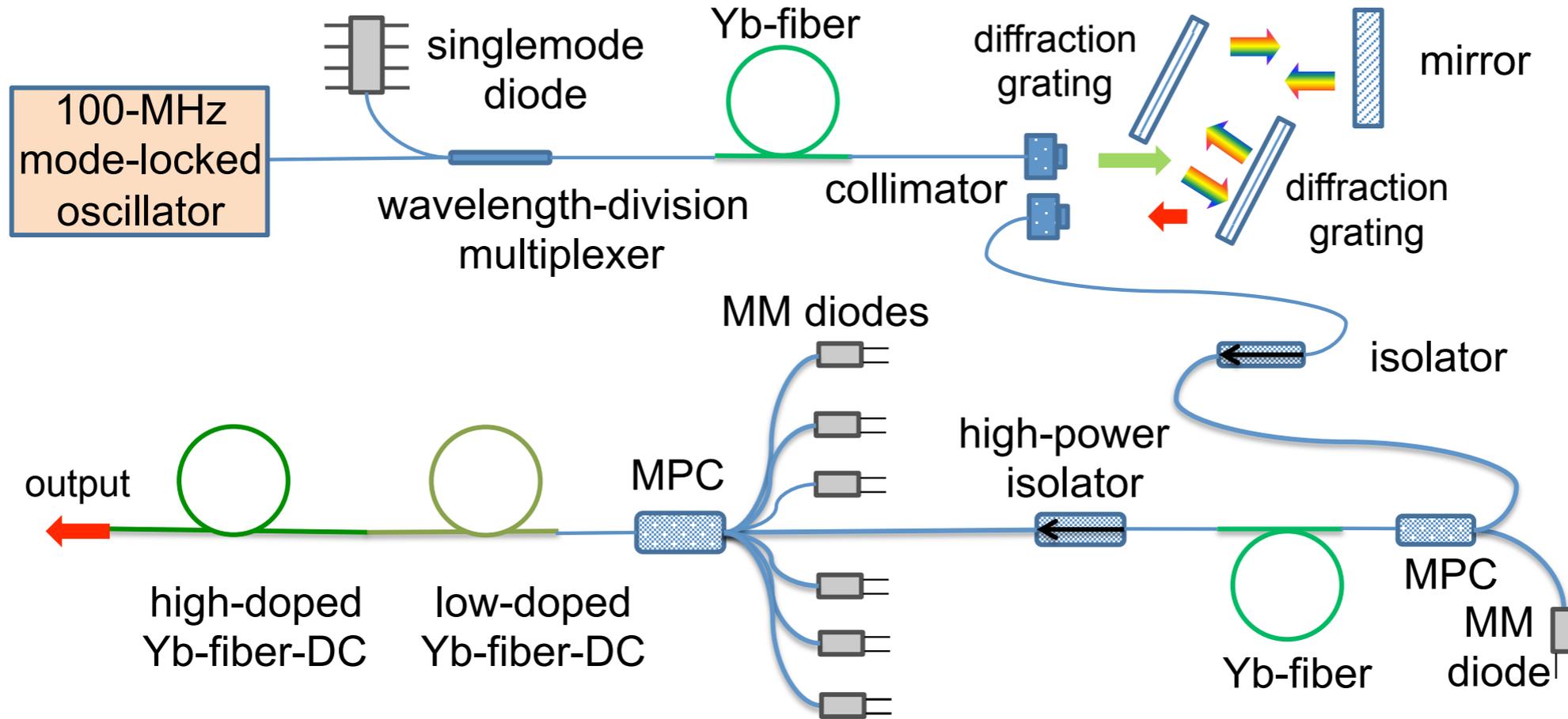
# Frekans $\text{Cs}$ atom saatine kilitli lazer sistemi



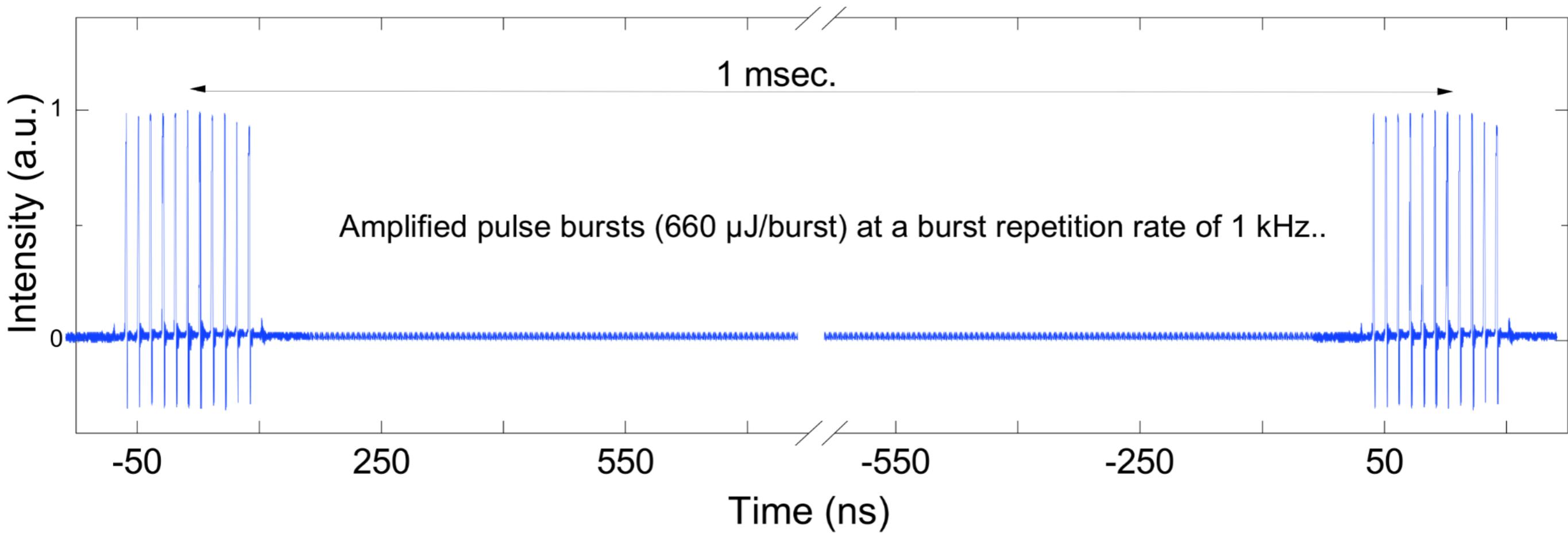
# Kilitli freaks



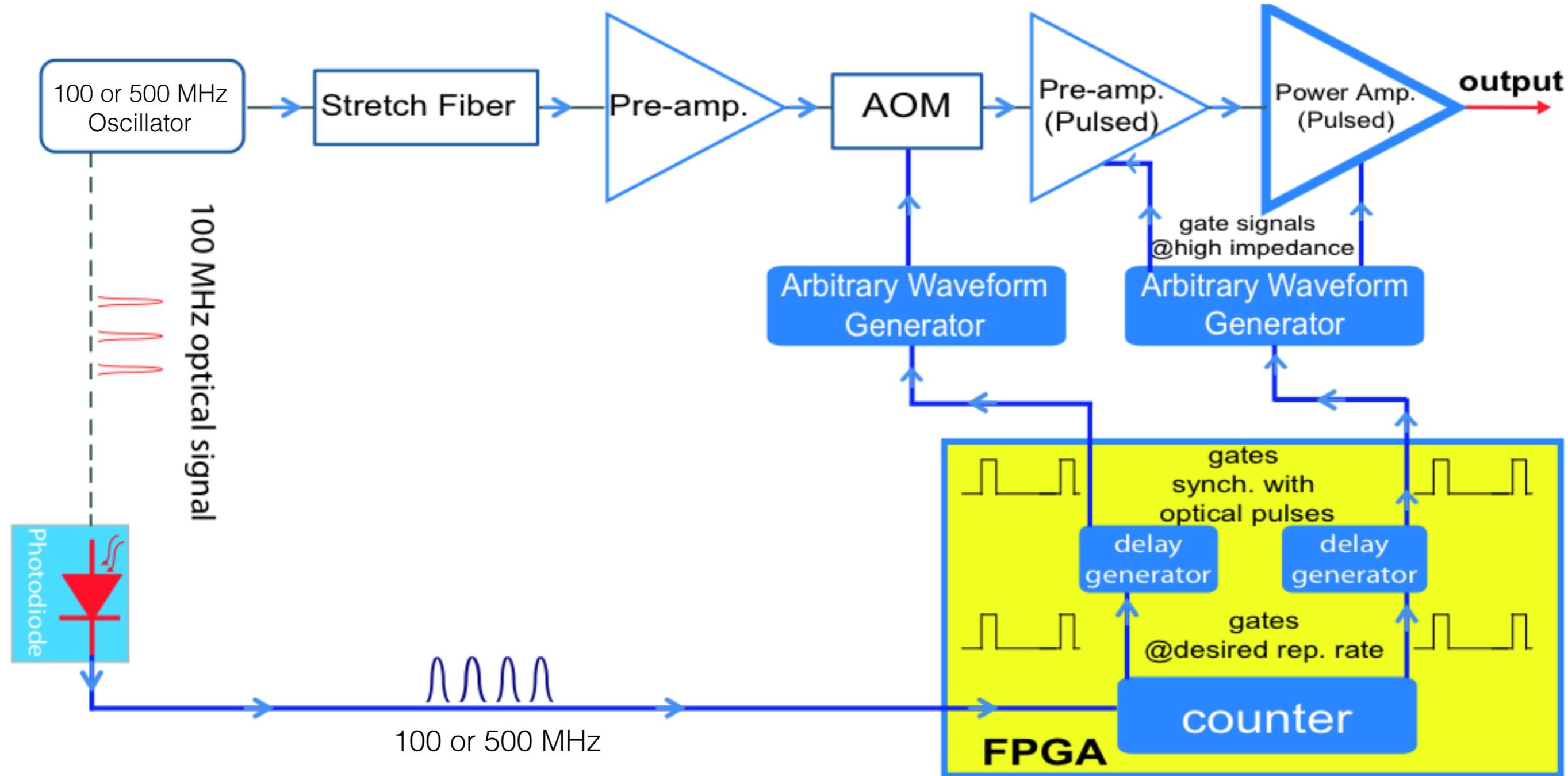
# Yüksek güçlü lazerler: 100 W, 5 ps, 100 MHz



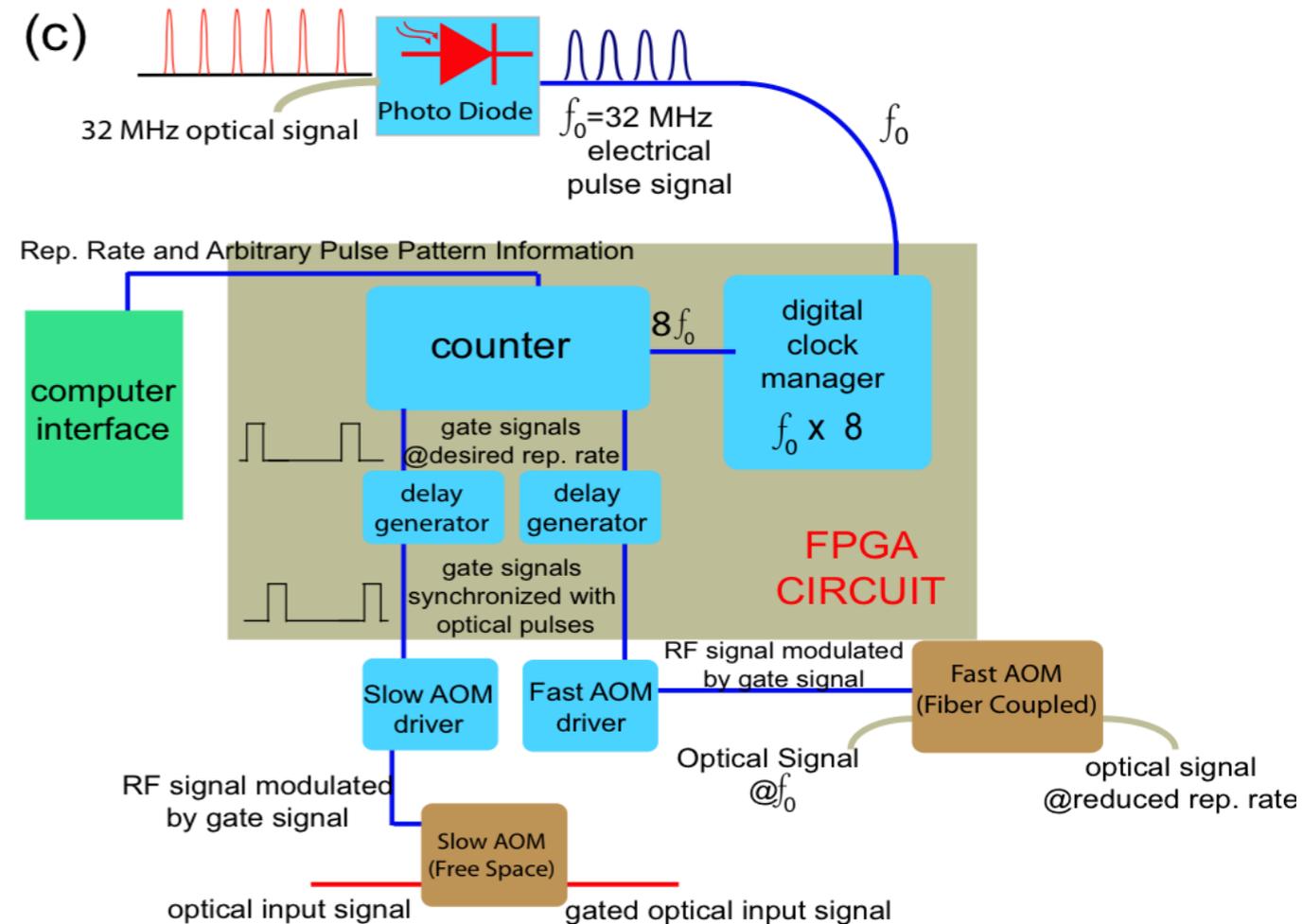
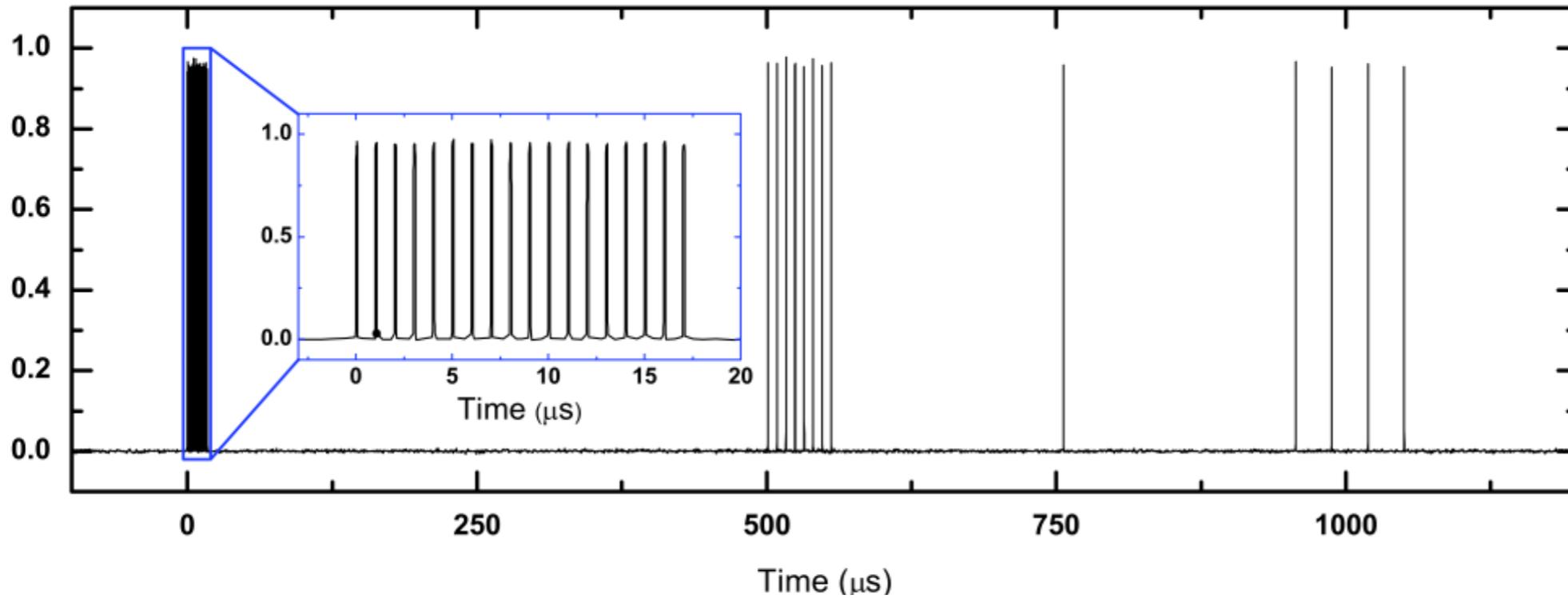
# Küme atımlı lazerler: 10 $\mu\text{J}$ , 150-250 fs



# Küme atımlı lazer mimarisi



# Rastgele atım treni sentezlenmesi (FPGA + AOM)



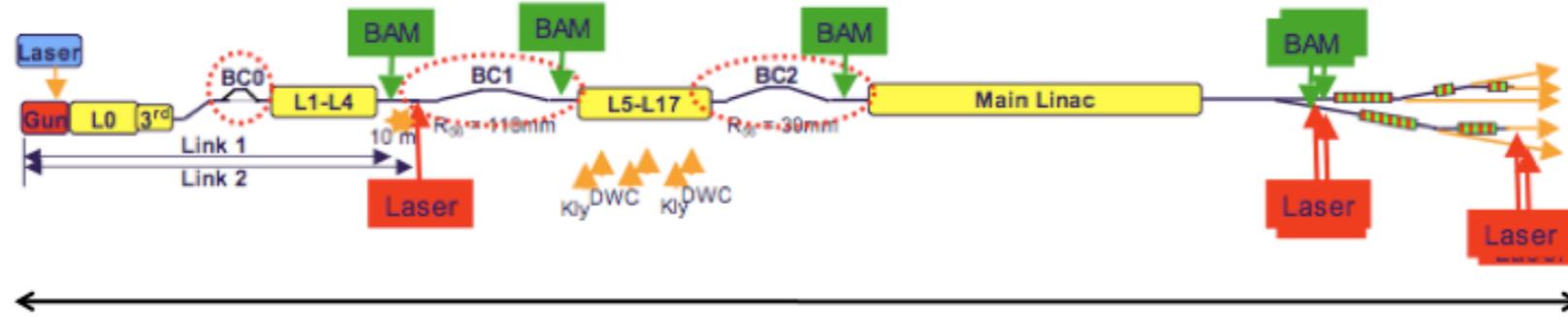
# Hızlandırıcı Uygulamaları

# İlgili olabilecek kapasiteler

- Fotoenjektörler için fiber lazerler
- Gürültü karakterizasyonu: genlik ve faz
- Stabilization ve geribesleme için elektronik
- Lazer-RF kilitleme
- Lazer-lazer kilitleme
- Optik tabanlı zamanlama ve frekans referans dağıtımı
- Lazer-malzeme işleme (tuzluk delmek)
- Yüzey yapılandırma

# Hızlandırıcı senkronizasyonu

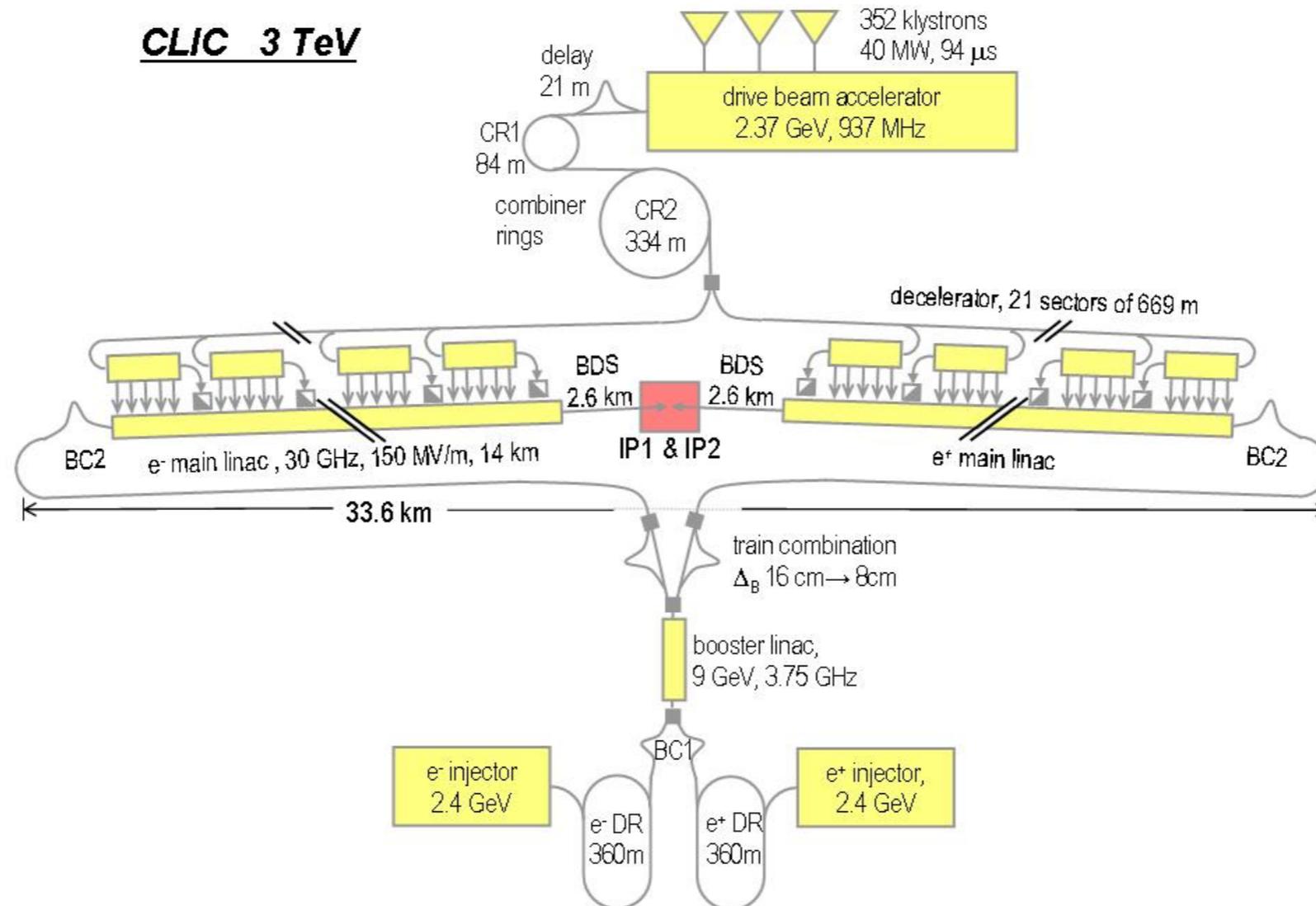
## DESY



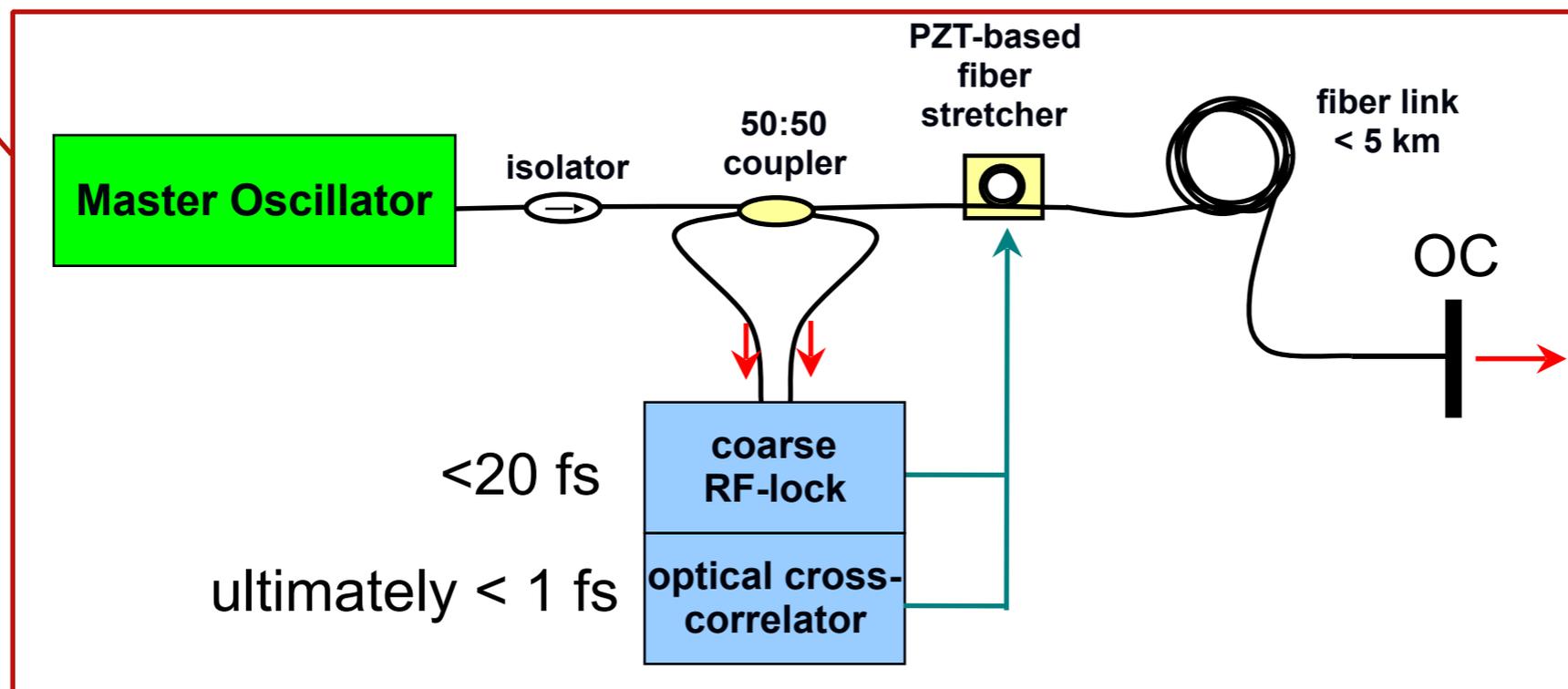
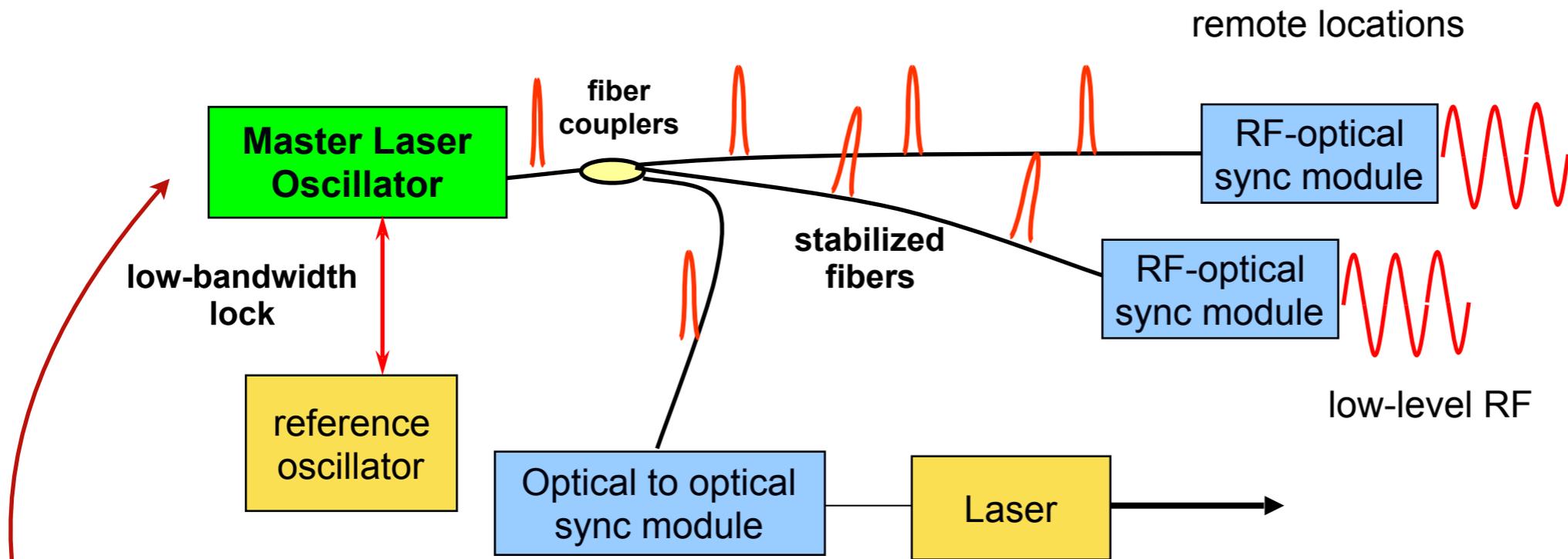
3.5 km

- Yeni ışık kaynakları ve hızlandırıcıların femtosaniyelik senkronizasyona ihtiyacı var.
- Gerekli hassasiyet RF tekniklerinin kapasitesinin ötesinde.

## CLIC

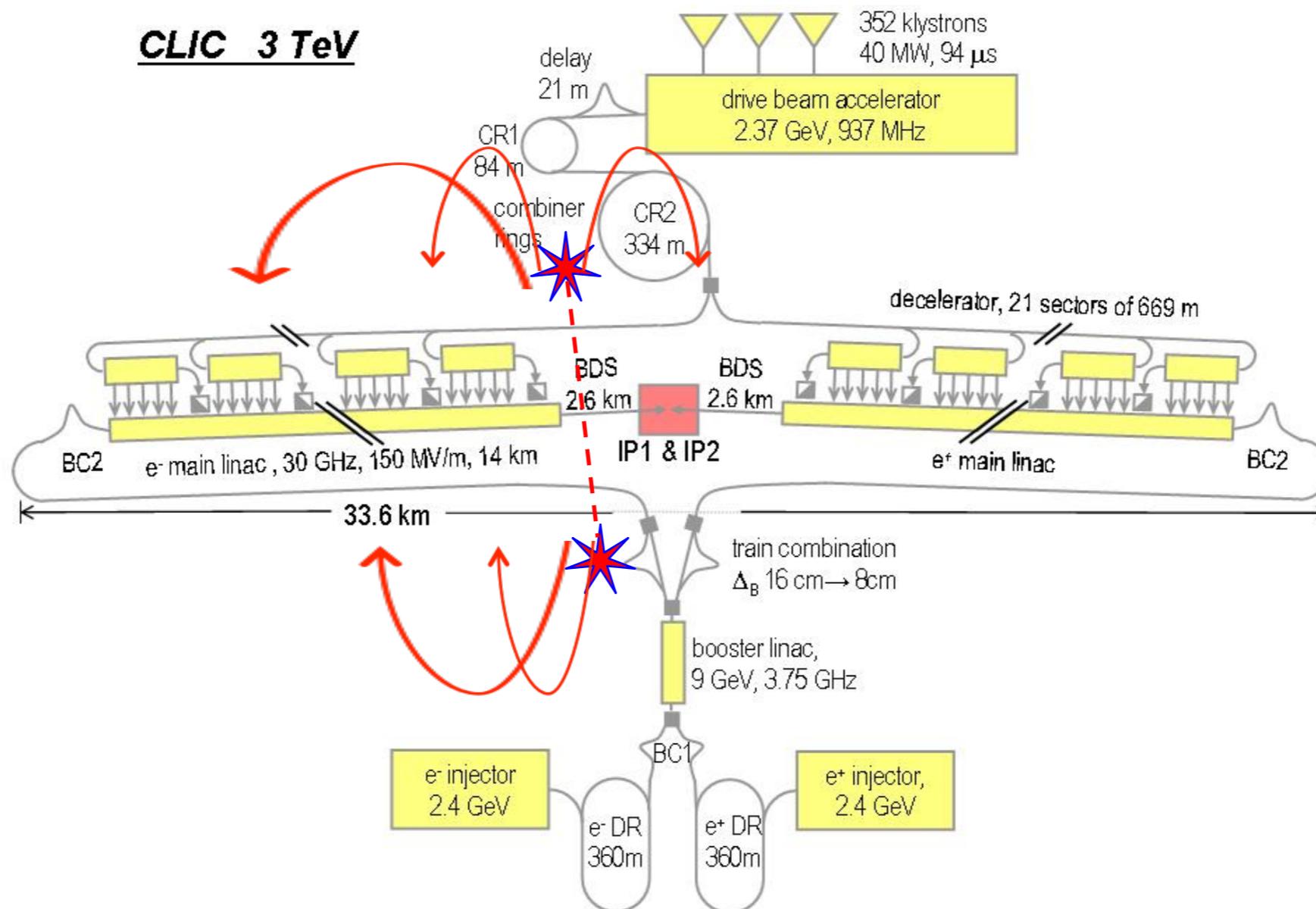


# Hızlandırıcıların optik senkronizasyonu

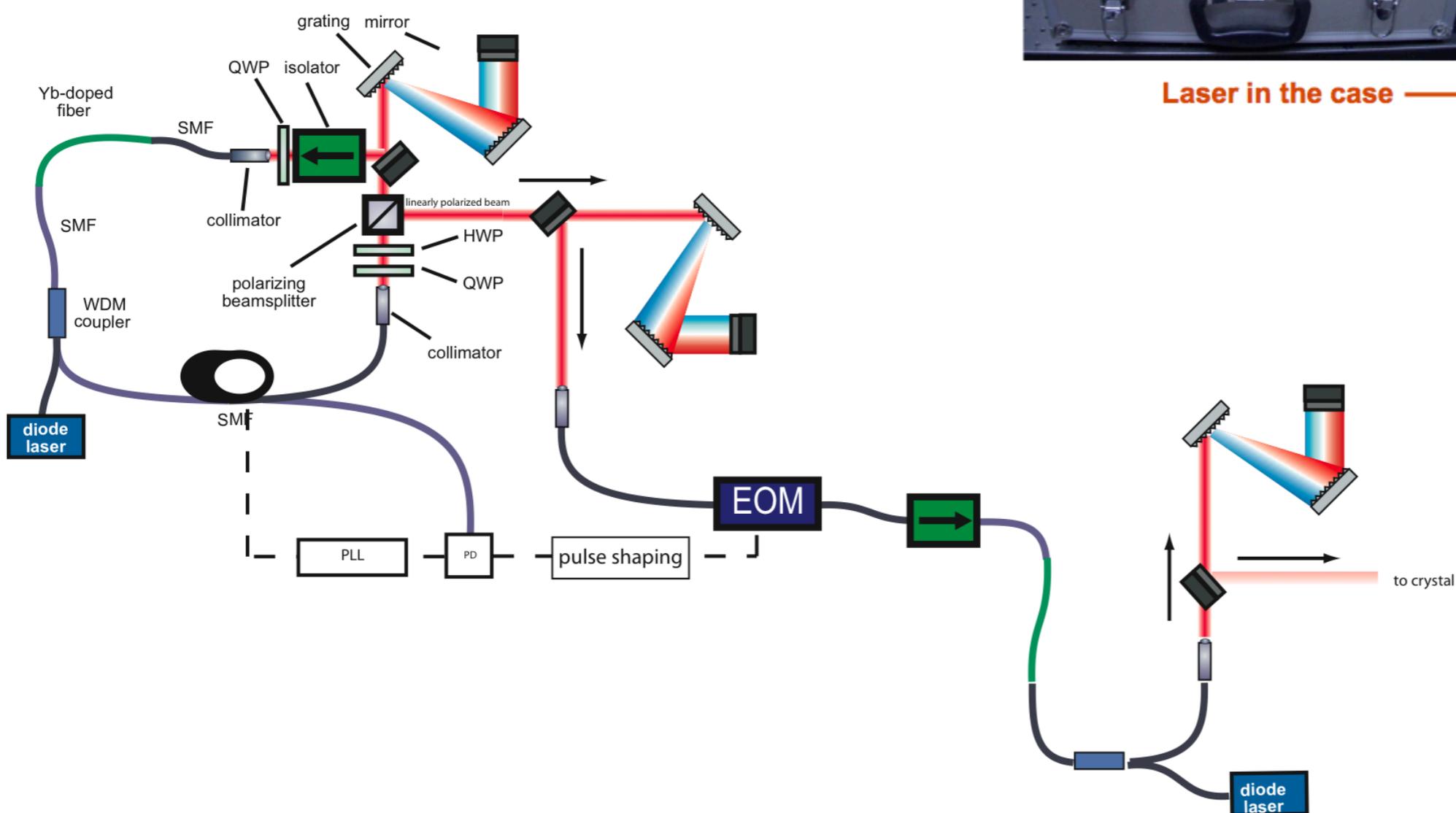
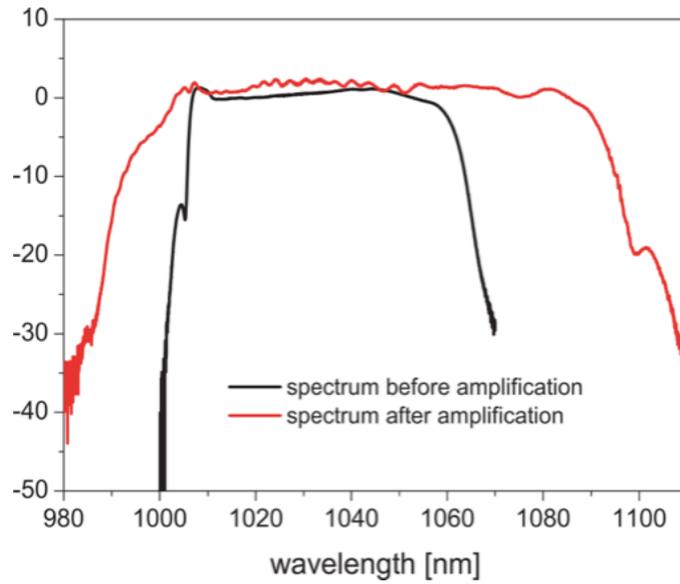


# Olay ufku ötesinde senkronizasyonun korunumu

- Laser frequency combs locked to a precise quantum transition, can be absolutely stable
- Position one at each major point, distribute sync signal locally as before.
- Use long links to keep each clock locked to each other (slow corrections)
- Distribution of frequencies with  $10^{-14}$  precision has been demonstrated.



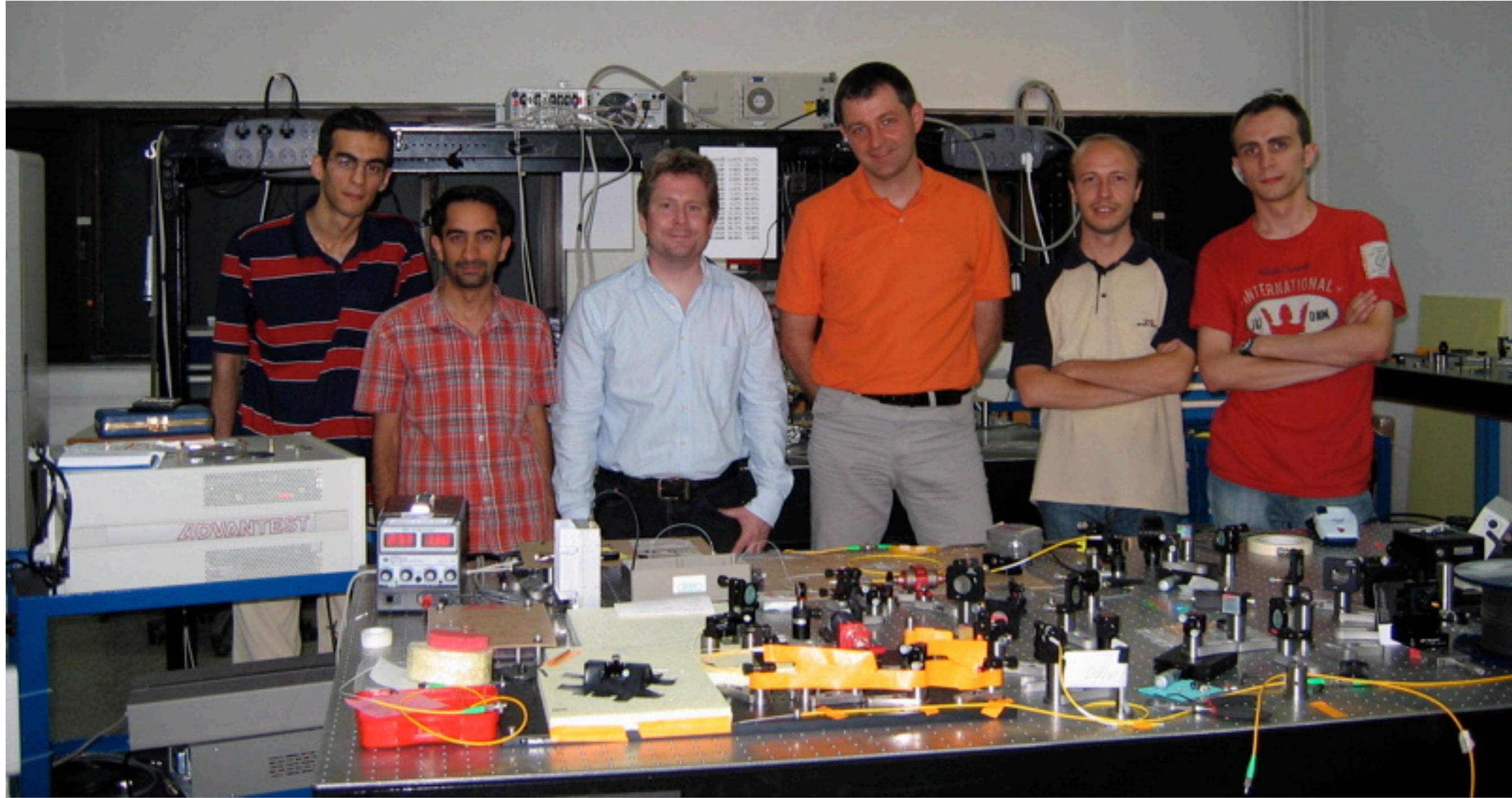
# DESY, Almanya için elektron demeti karakterizasyon lazeri

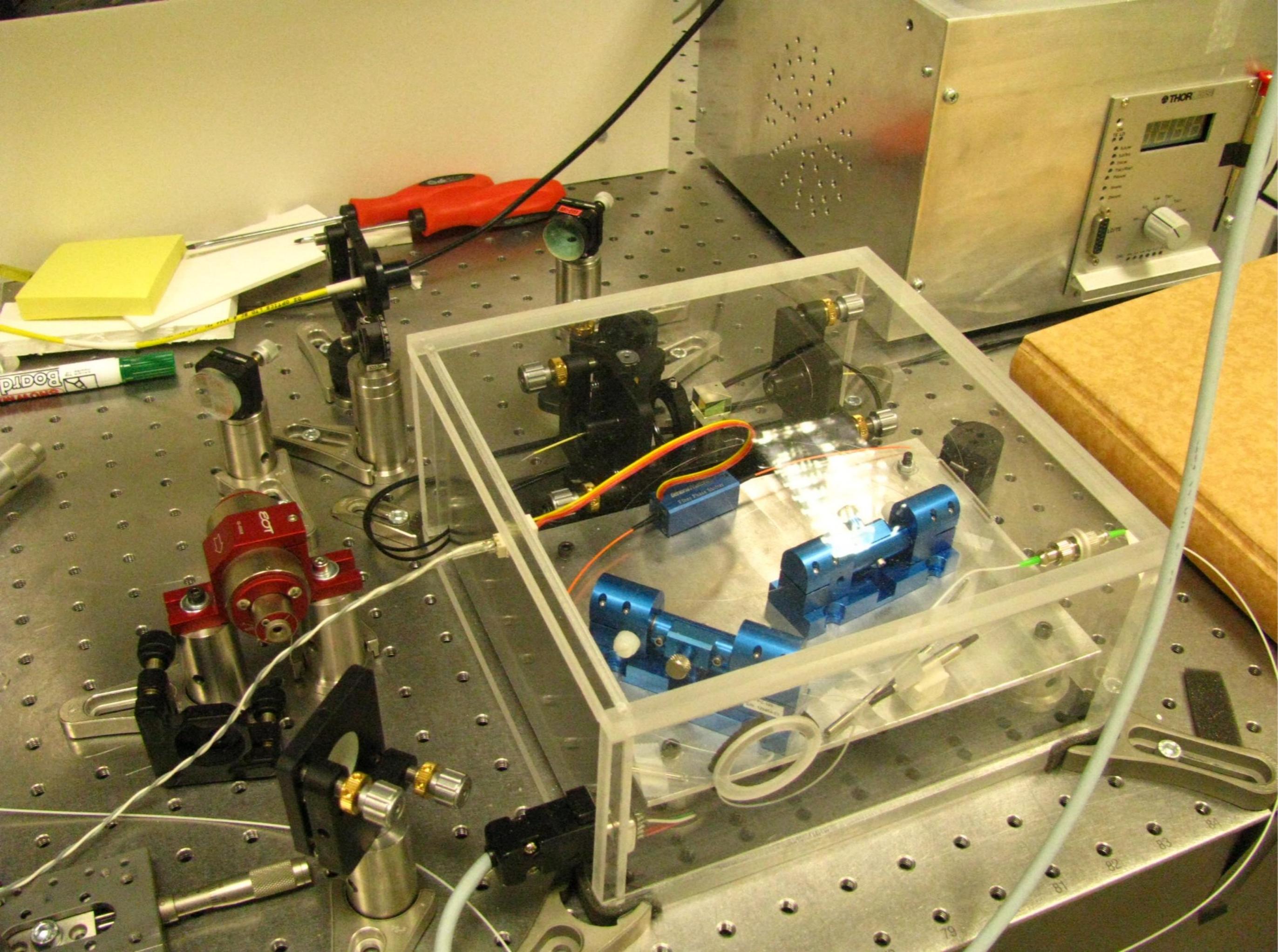


Laser in the case



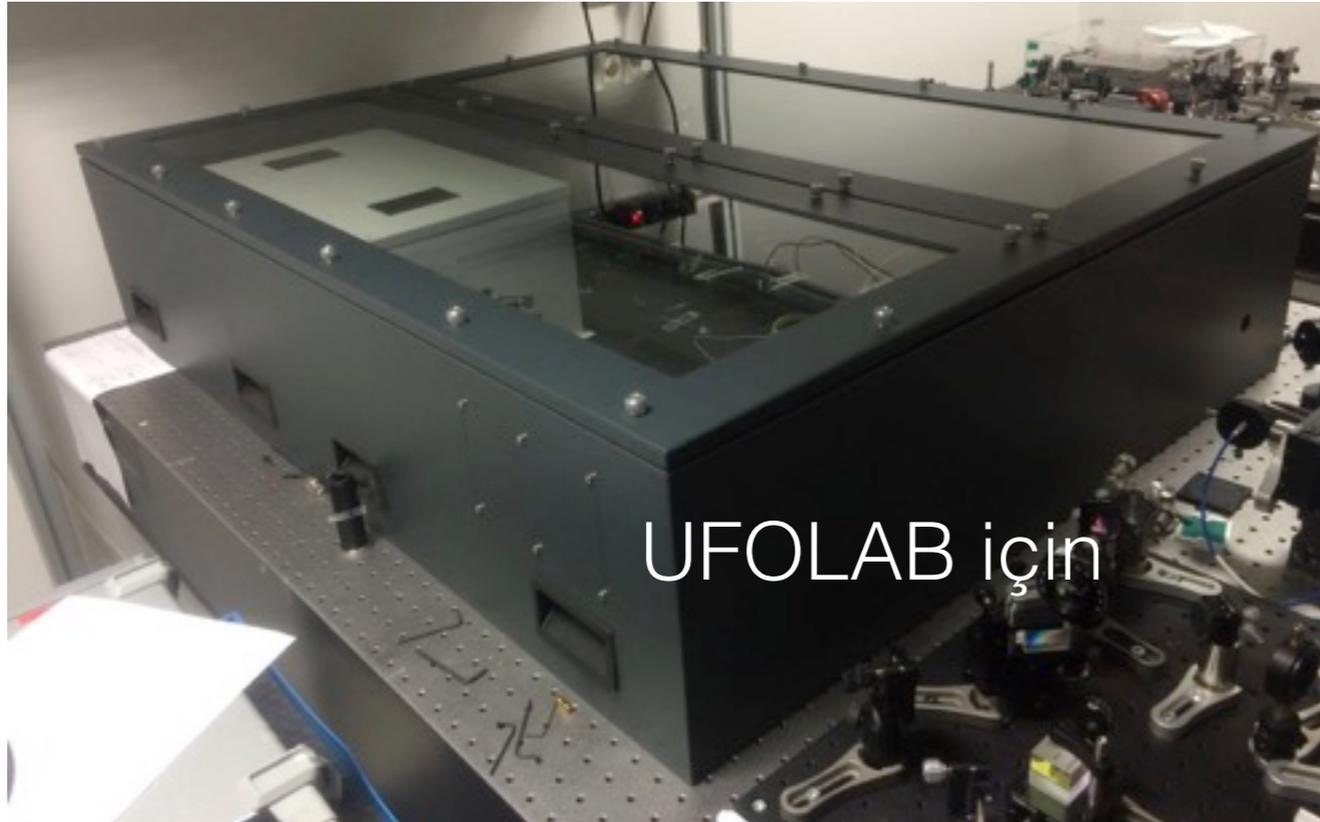
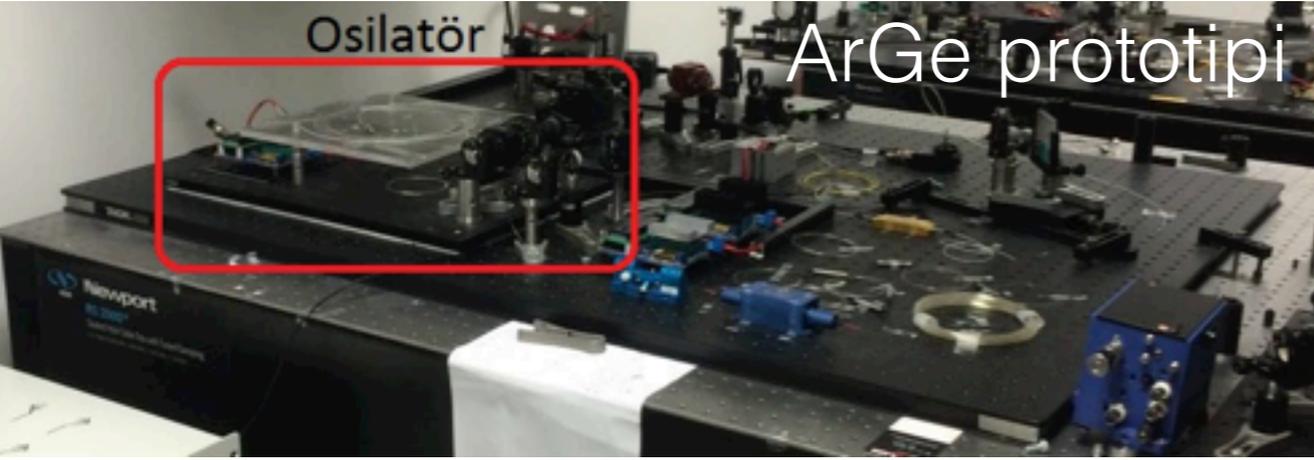
# FERMI, İtalya için senkronizasyon lazeri





# EndüstriyelEtleřtirme Faaliyetleri (FiberLAST A.ř.)

# Femtosaniye lazerlerin endüstriyelleştirilmesi

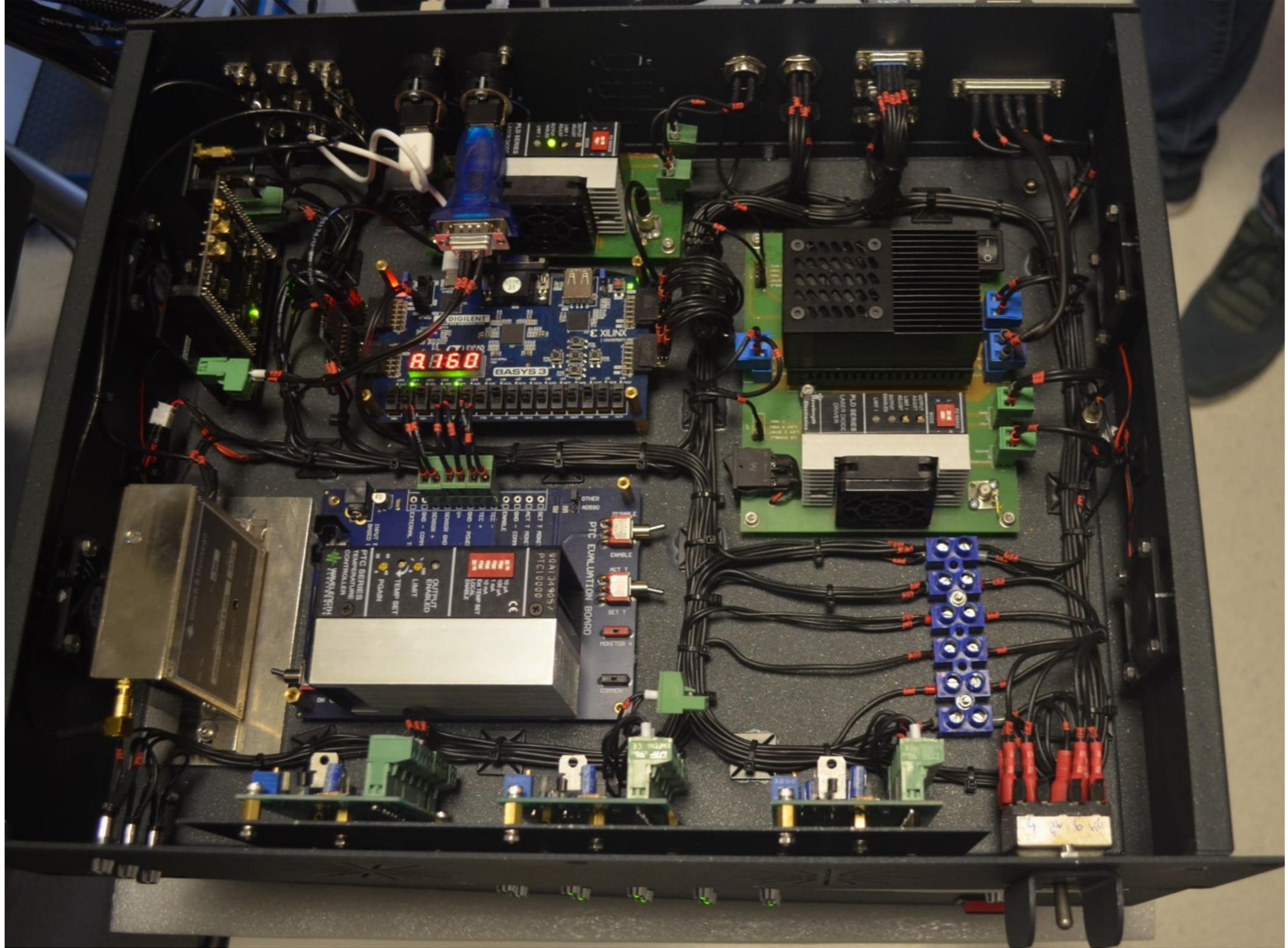


# Femtoseaniye lazerlerin endüstriyelleştirilmesi

Toronto Üniversitesi için

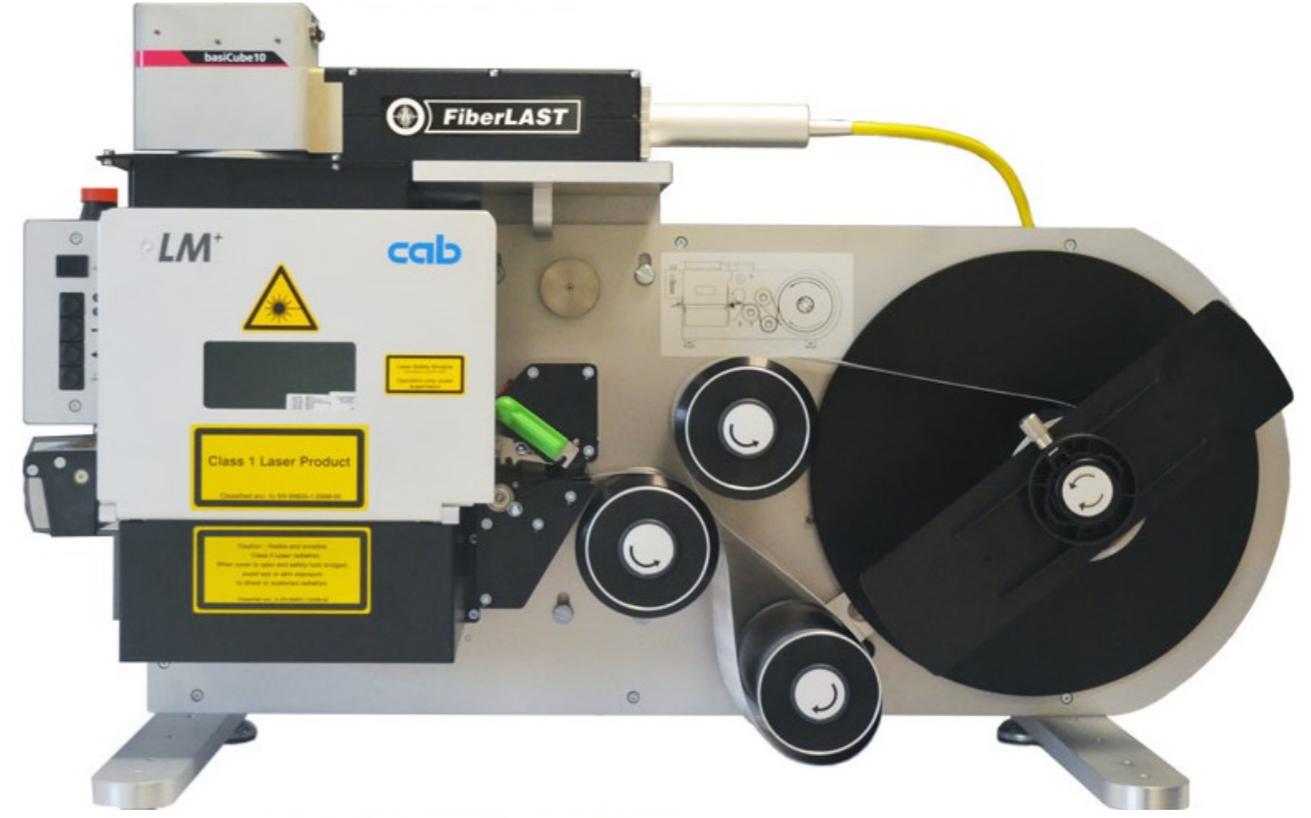


# Femtosekime lazerlerin endüstriyelendirilmesi



Özgün tasarım ve yerel üretim kontrol elektroniği

# Nanosaniye ve CW çeşitli endüstriyel lazerler



**nanomARK HD**



Kullanımda ~200 endüstriyel ürün

# Eđitim Faaliyetleri

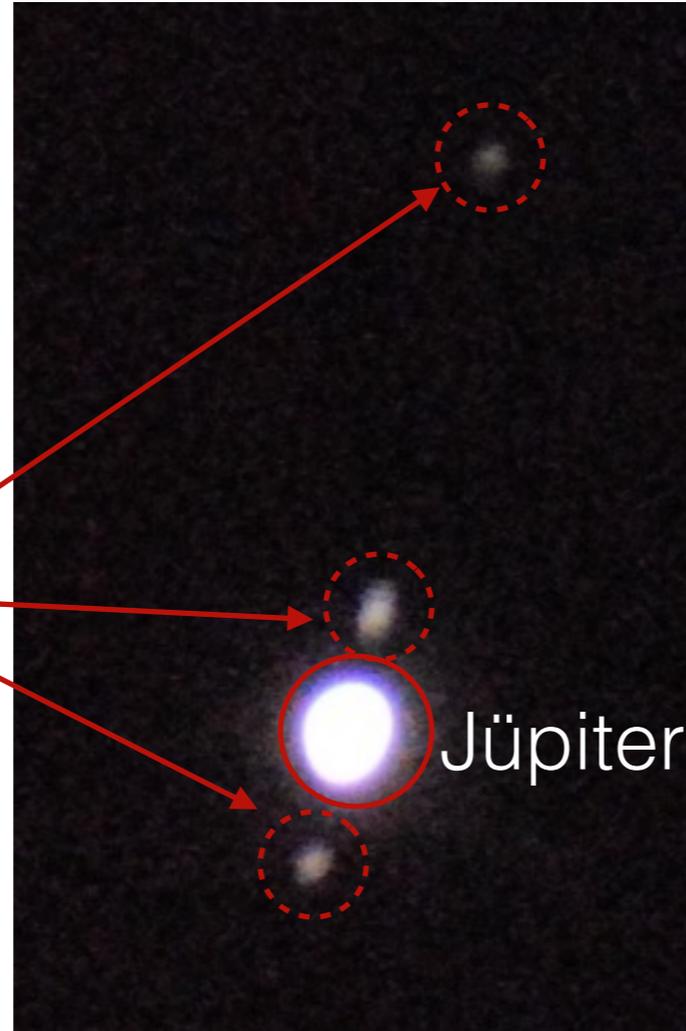
# PHYS 211-212 derslerinin projeleri

- PHYS 211: Mekanik dalgalar, optik ve termodinamik
- PHYS 212: Modern fizik

Vakum odacıđı



Teleskop



Jüpiter'in ayları

Jüpiter

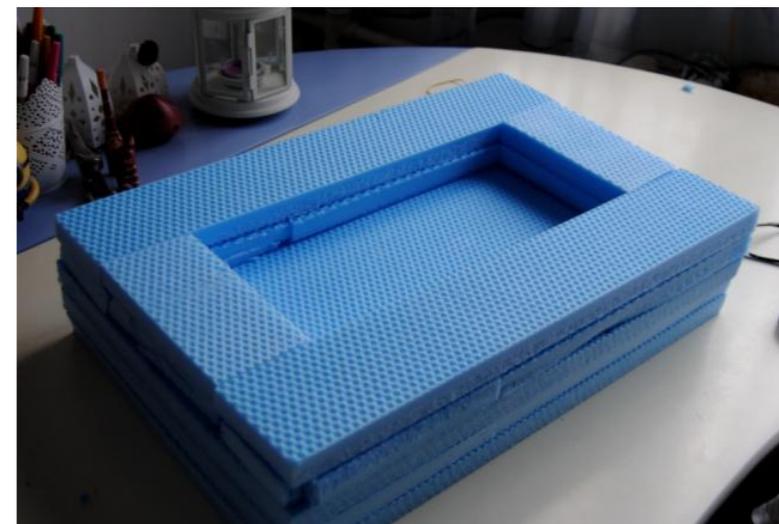
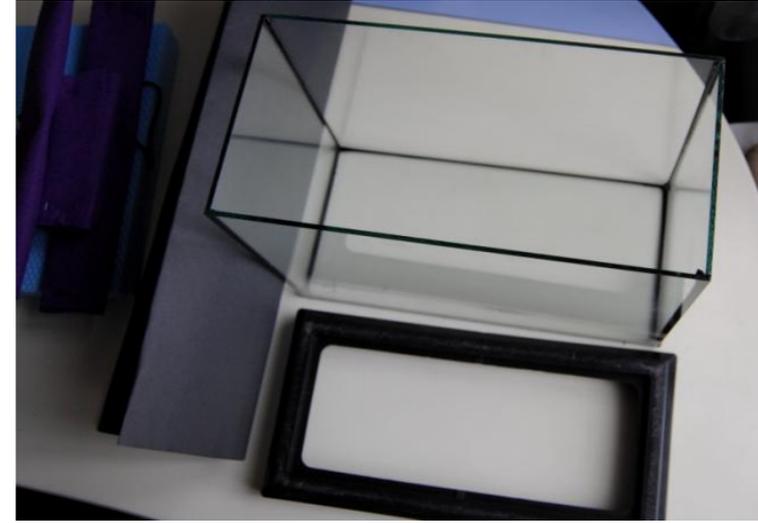
Manyetik uçuş



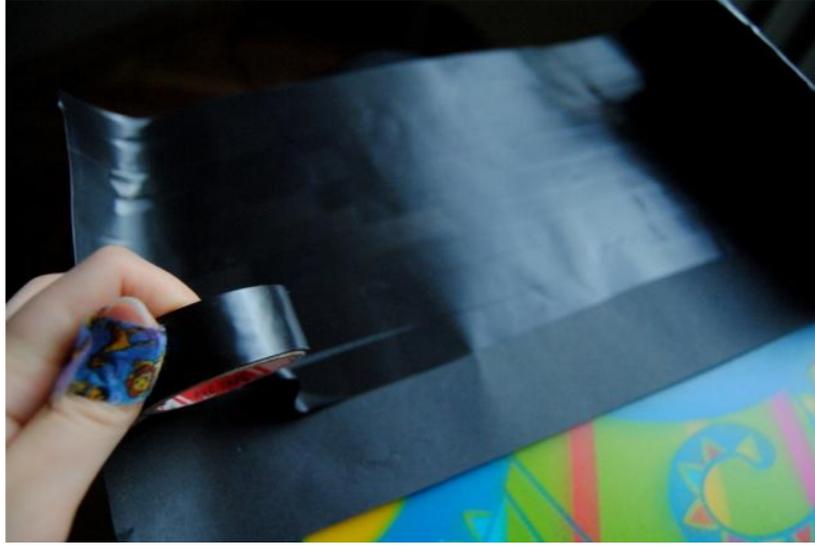
Tesla sargısı



# Bulut odacığı (cloud chamber) - Bükem Belen



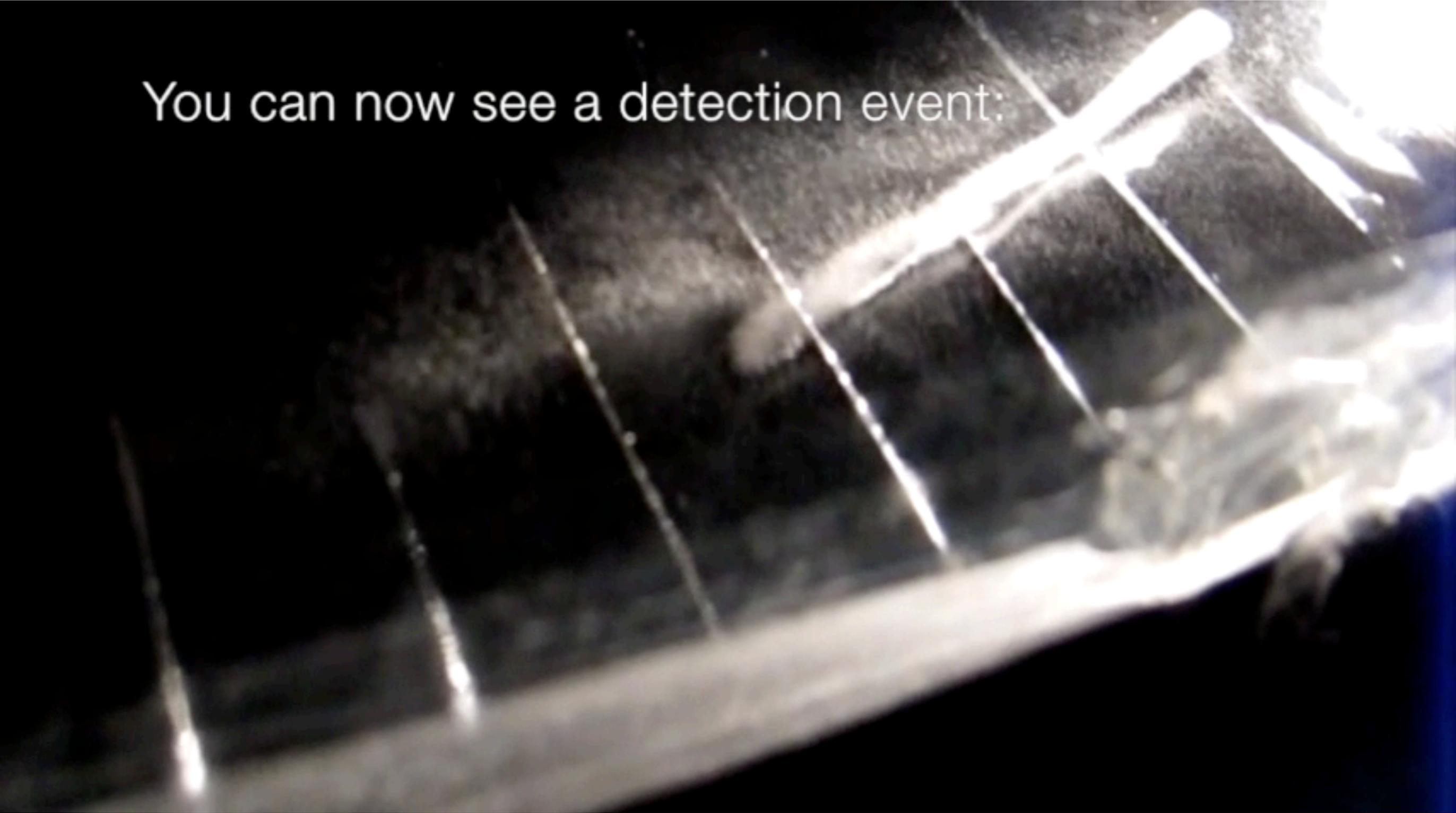
# Bulut odacığı (cloud chamber) - Bükem Belen



100 ml izopropanol alkol ve 1 kg kuru buz

# Kozmik parçacık dedektörü

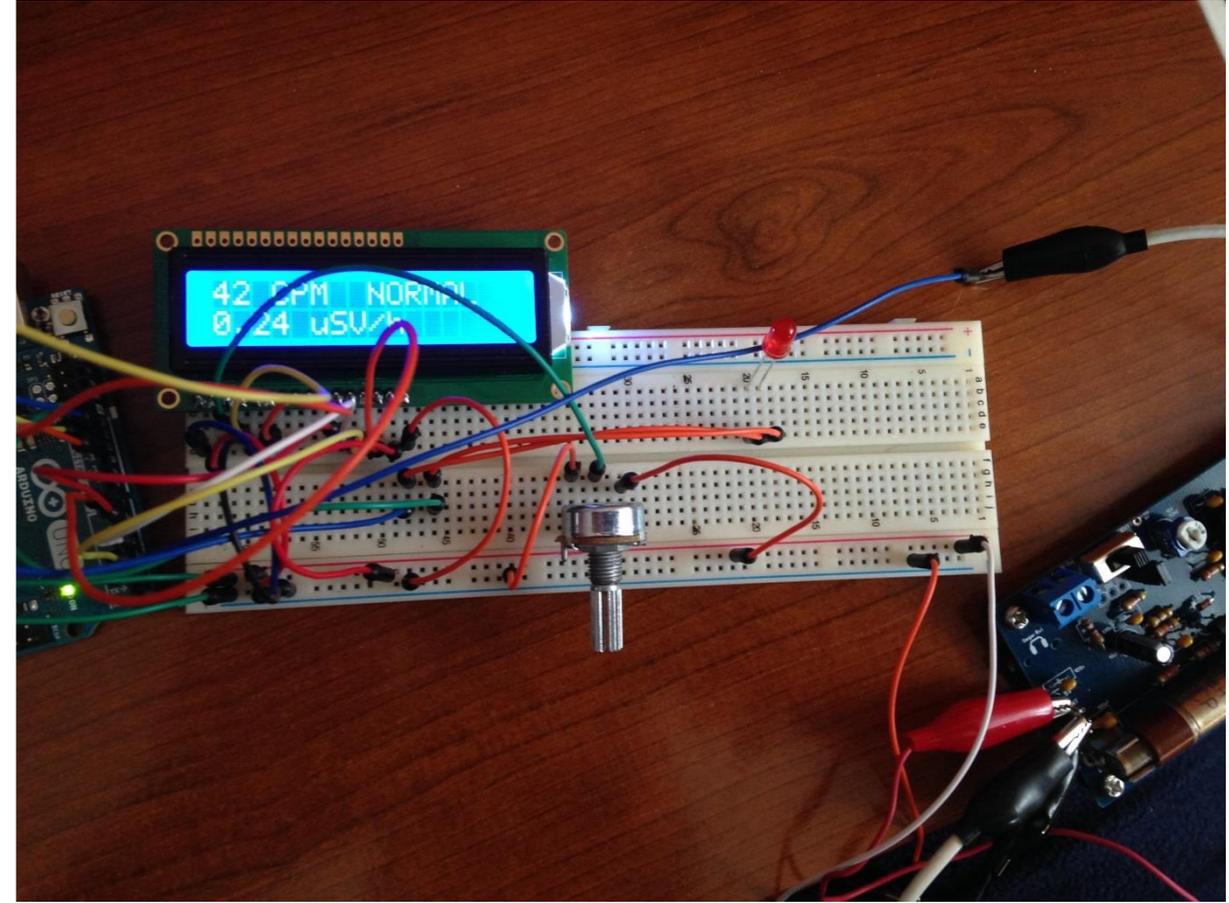
You can now see a detection event:



# Gayger sayacı - Emir Olgun



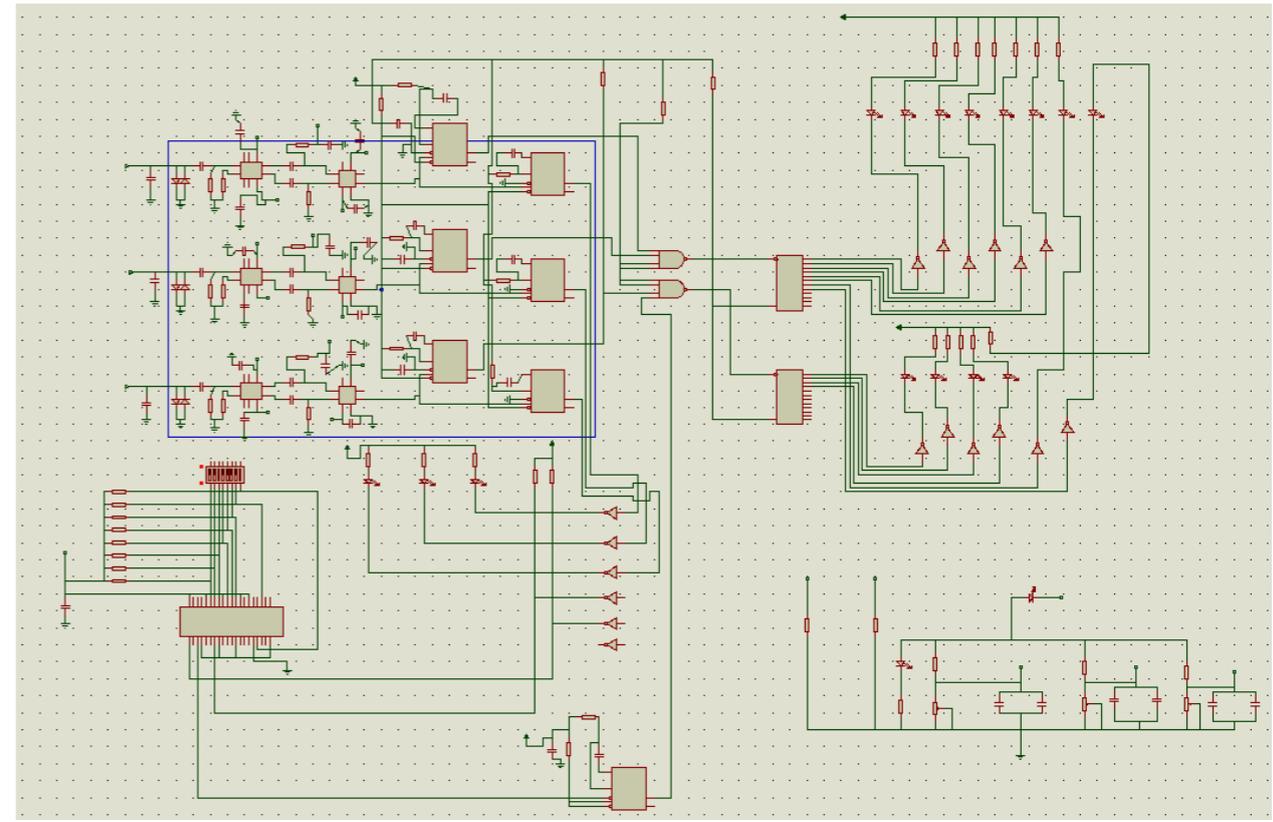
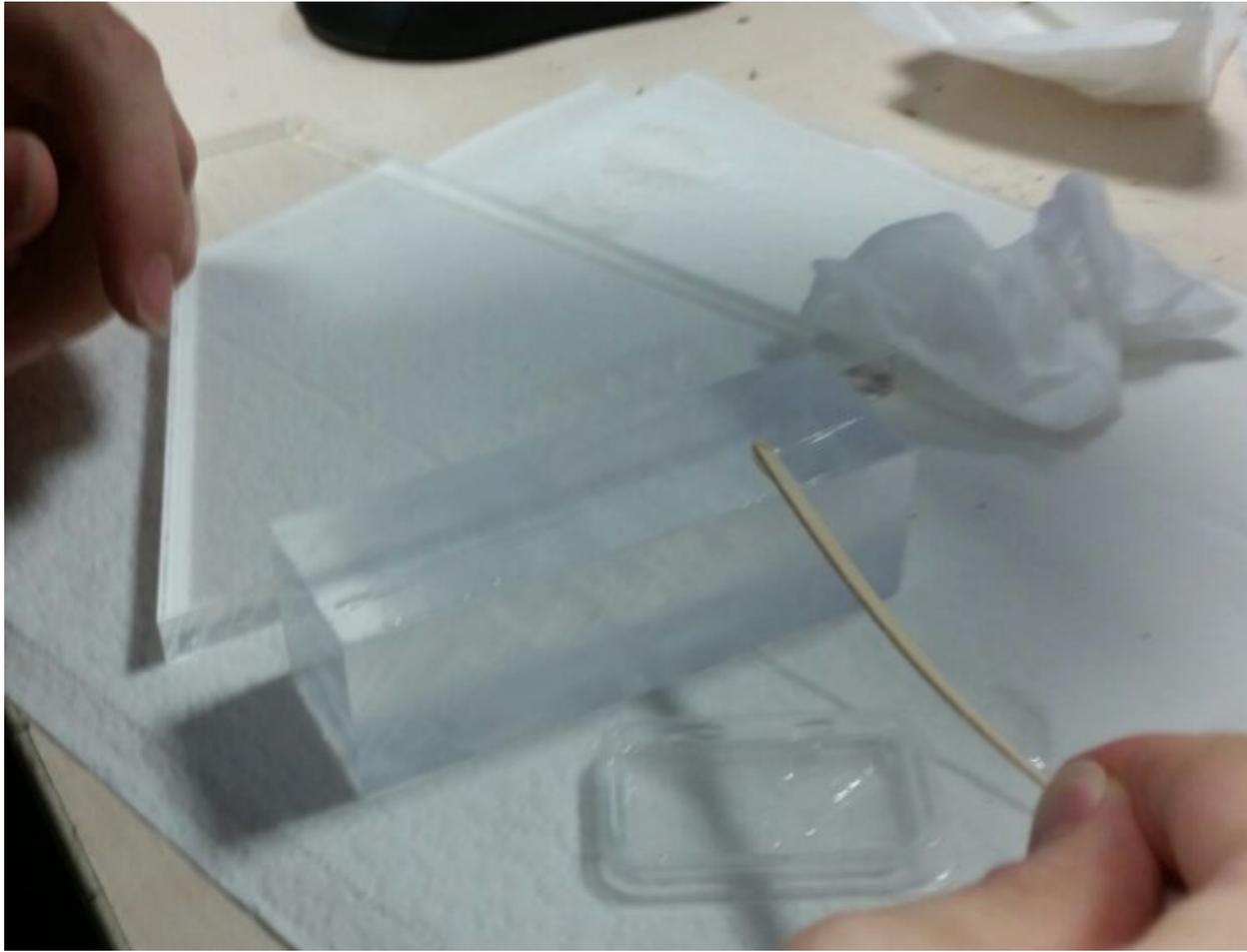
SMB-20  
(Sovyet yapımı)



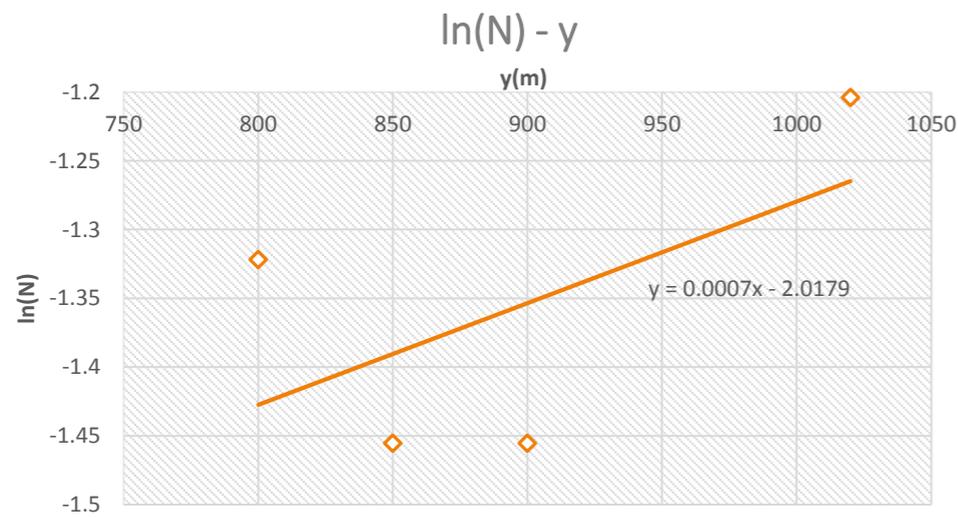
Arduino tabanlı ev yapımı devre



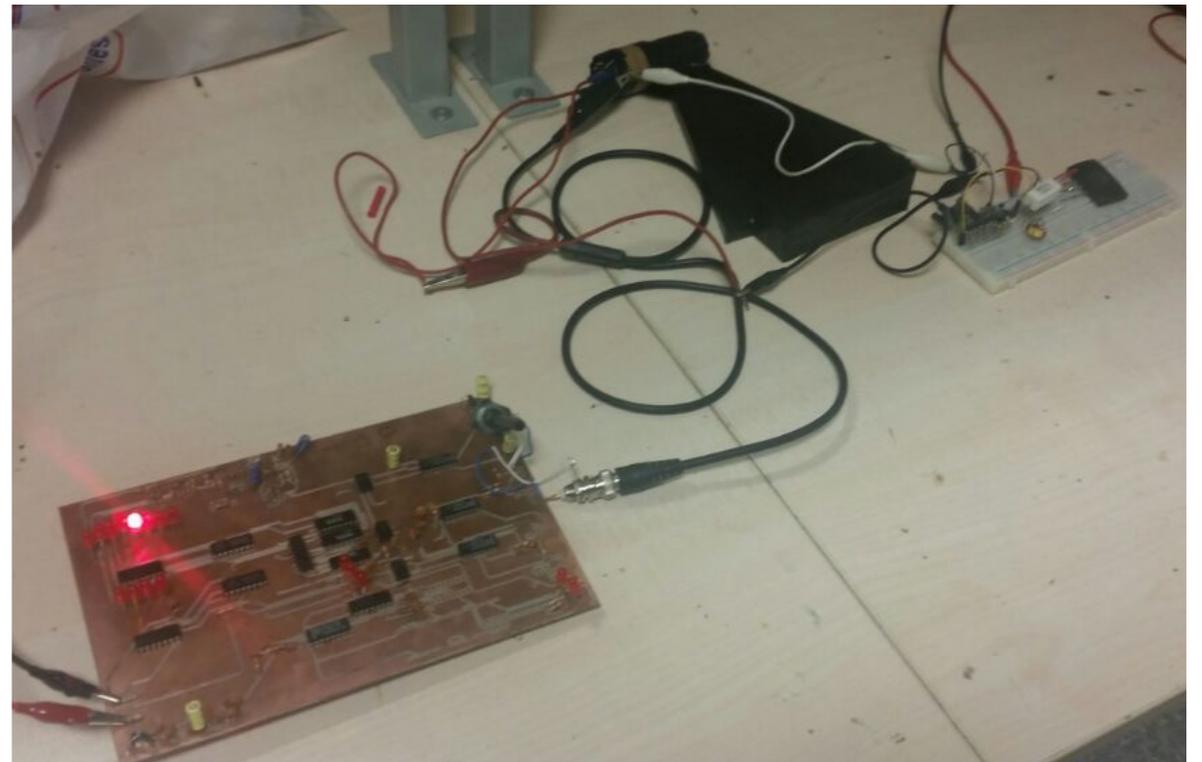
# Sintillatör - A. B. Çatlı - S. S. Kahraman - Z. Ahsan



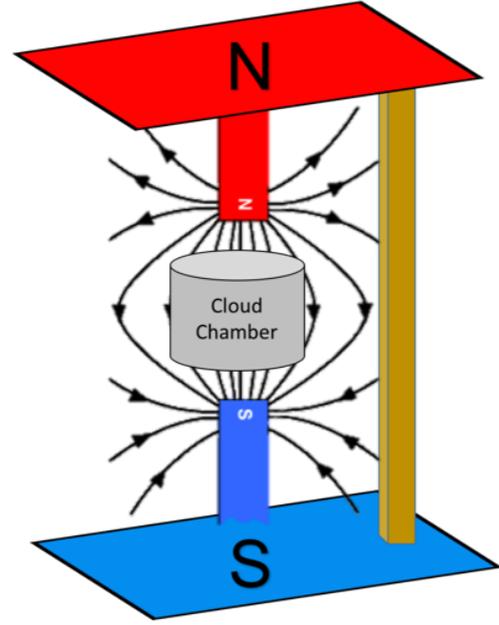
ev yapımı  
sayaç devresi



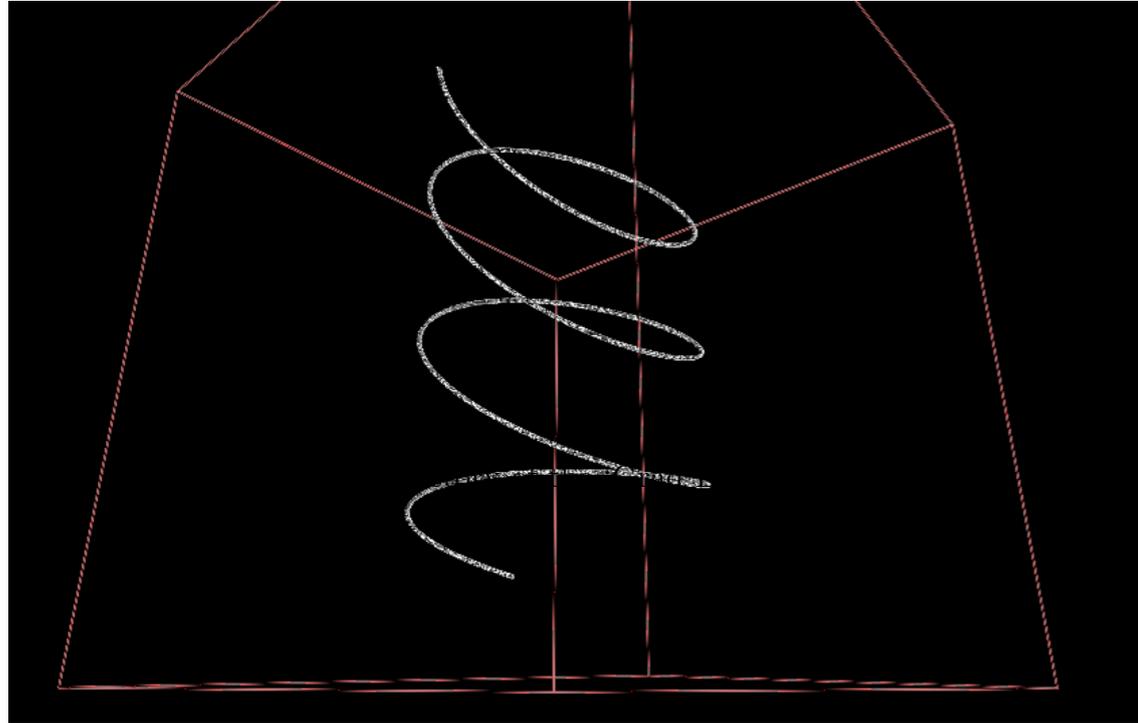
deneysden hesaplanan  $\gamma \sim 2.4$  (gerçek  $\sim 9$ )



# Parçacık - Anti-Parçacık Üretimi Gözleme Denei - S. F. Öztürk



düzenek



Matlab simulasyonu



Fon kaynaklarına teşekkürler:

ERC, TÜBİTAK, SSM