

# **Serial time-encoded amplified image for real-time observation of fast dynamic phenomena**

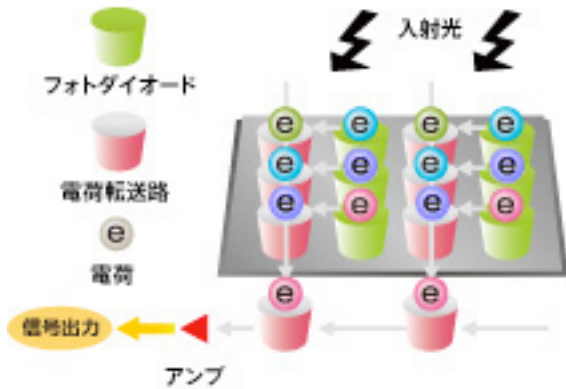
PD Yi-Da Hsieh

# Introduction

- Optical imaging is a widespread and versatile diagnostics and inspection tool in use today.
- High-speed optical imaging is an effective tool for real-time observation of fast dynamical events such as shockwaves, laser fusion.

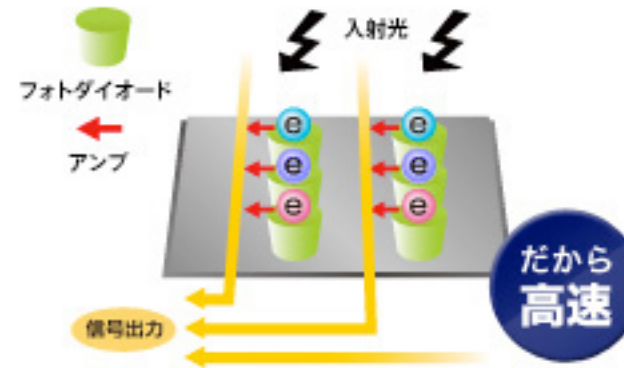
# Introduction

## CCD



光を電気(電荷)に変換したあと、一画素分ずつパケツリレーのように転送し、センサーの出口のアンプで増幅させて信号化します

## CMOSセンサー



それぞれのフォトダイオードにアンプがあるので、電気をその場で増幅させて信号化し、一気に伝送します

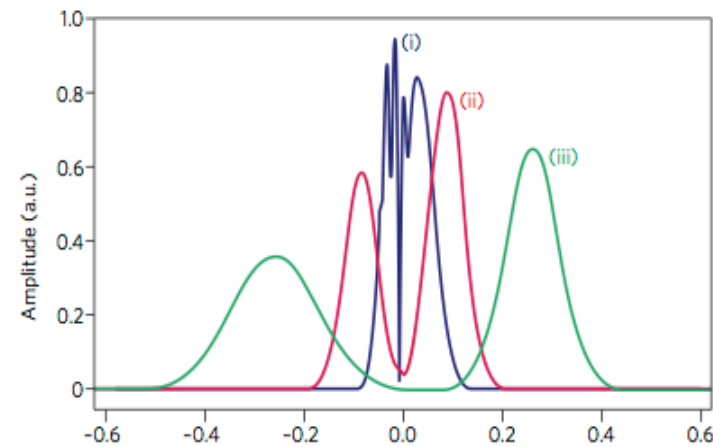
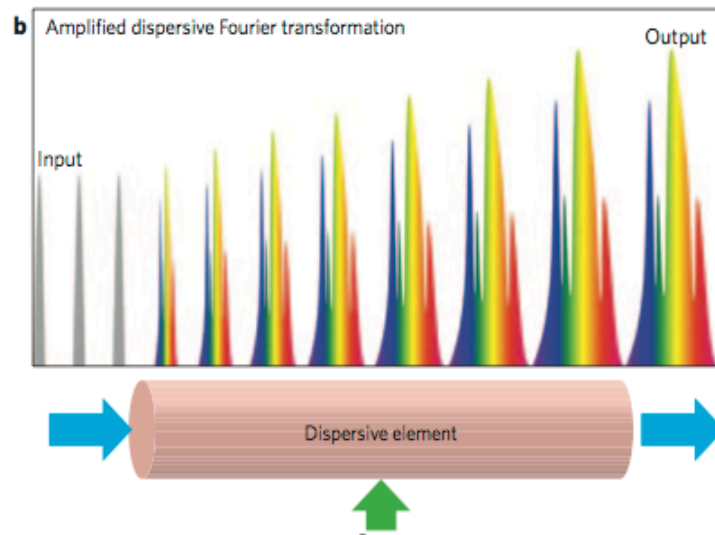
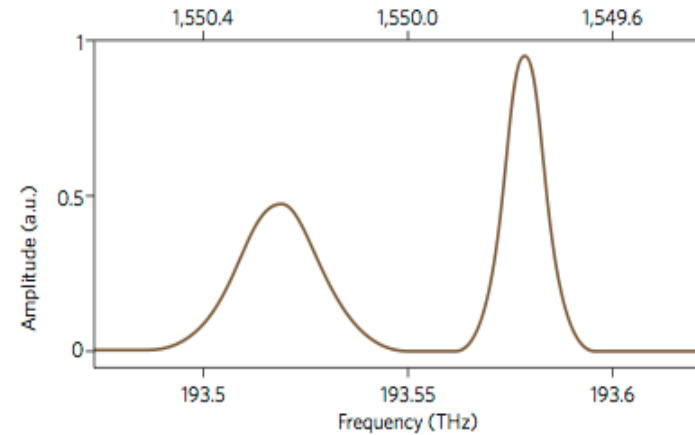
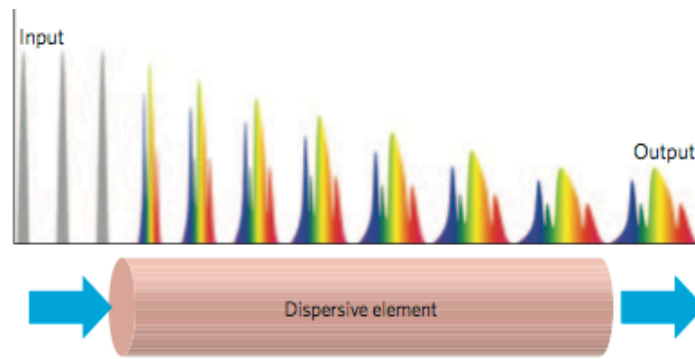
<1M fps

- Serial time-encoded amplified imaging/microscopy (STEAM) .

Ref: [http://www.sony.jp/cyber-shot/products/DSC-WX1/feature\\_1.html](http://www.sony.jp/cyber-shot/products/DSC-WX1/feature_1.html)

# Dispersive Fourier transformation (DFT) (分散フーリエ変換)

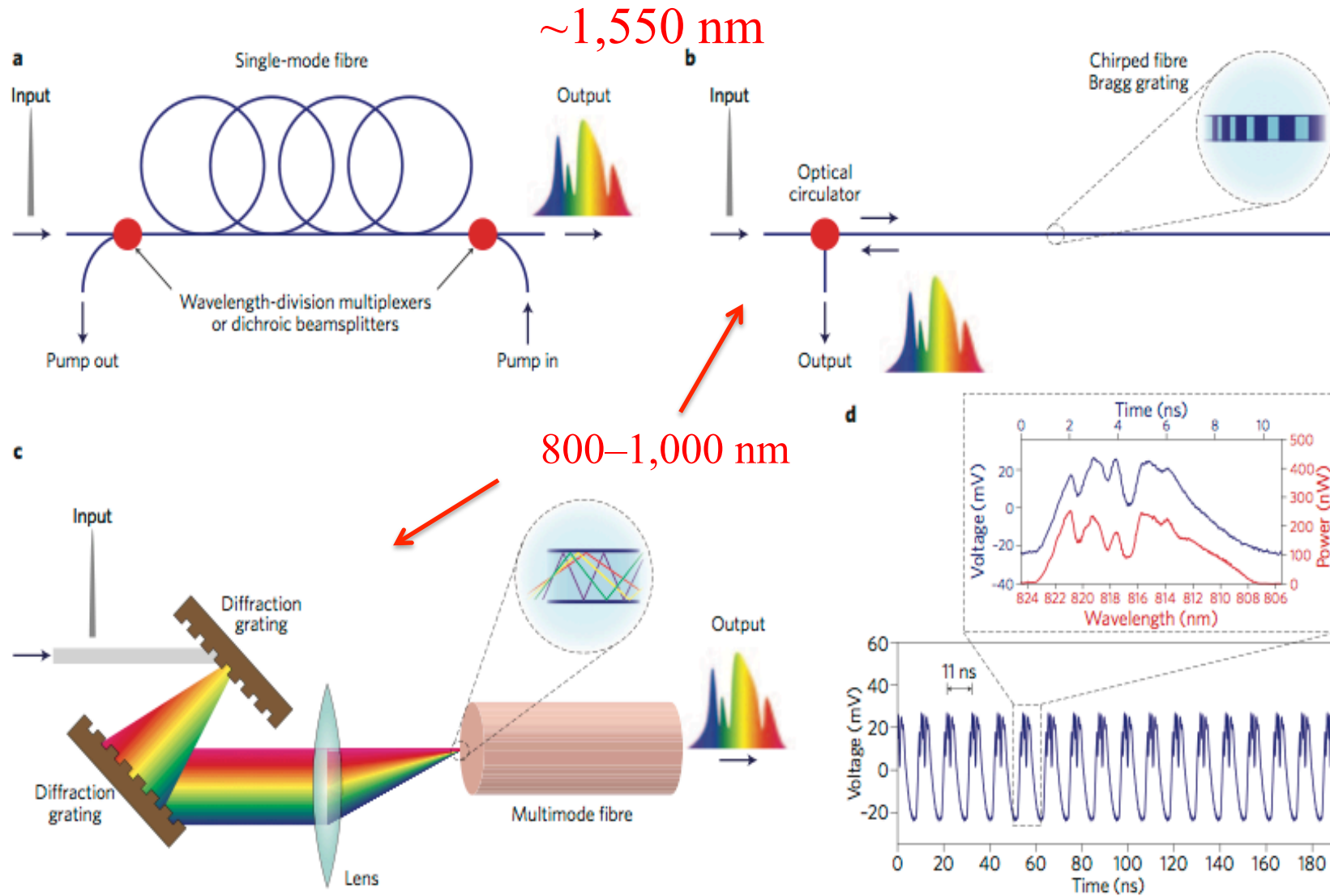
A sufficiently large and linear GVD



As a gain medium.

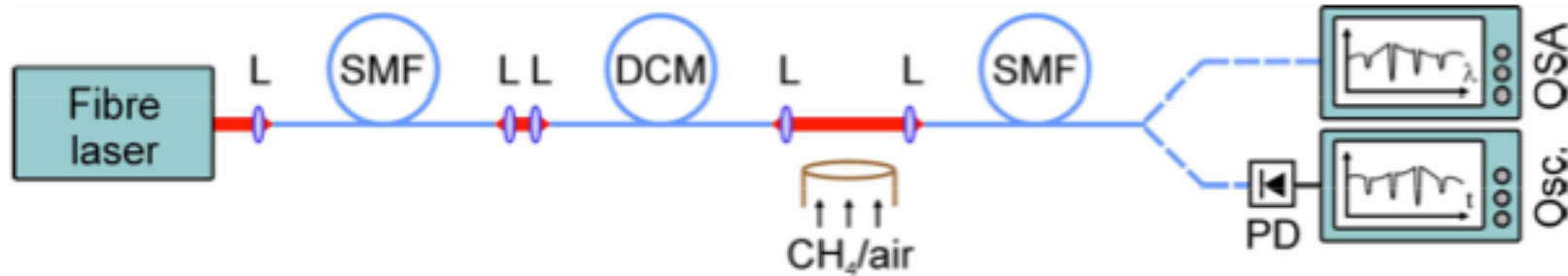
Ref: K. Goda, et al. (2013) *Nat. Photonics*, 7: 102.

# Method for DFT



# Gas spectroscopy

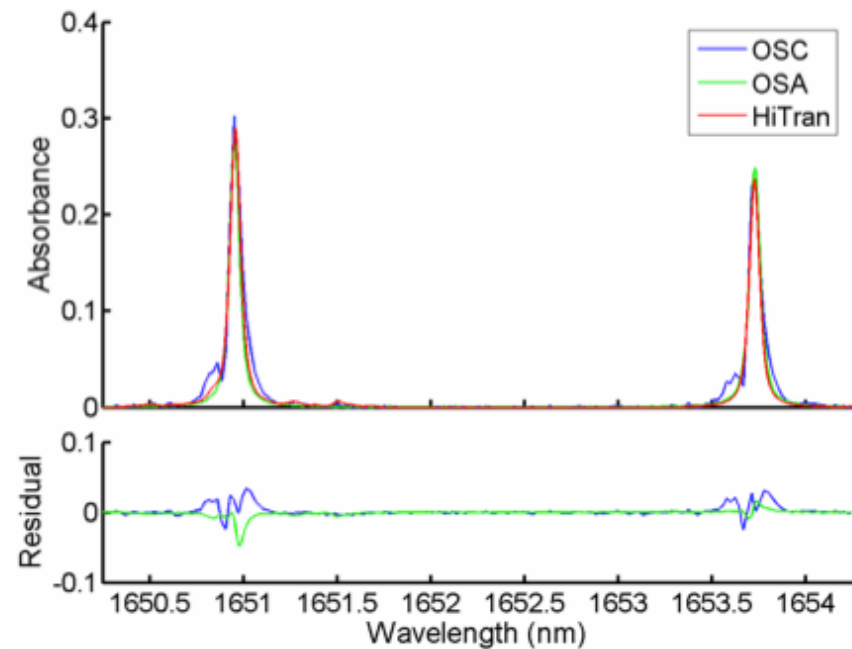
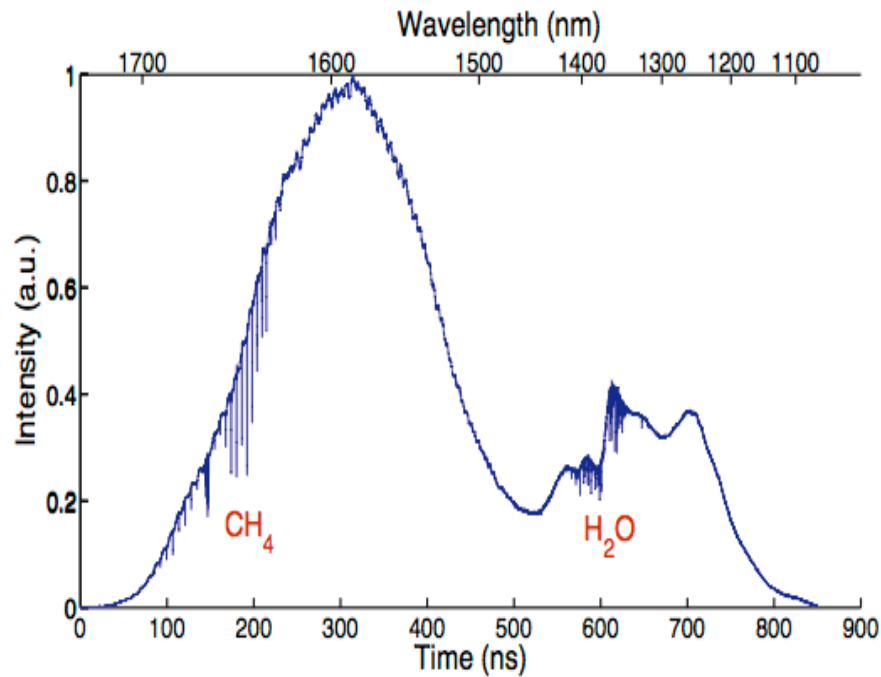
Spectral width: 600nm



- Mode-locked ytterbium fiber laser
  - Center wavelength: 1064nm.
  - Repetition rate: 1.133MHz
- 10 GHz bandwidth photodiode
- 8 GHz bandwidth real-time oscilloscope

*Ref: J. Hult, et al. (2007) Opt. Exp., 15: 11385.*

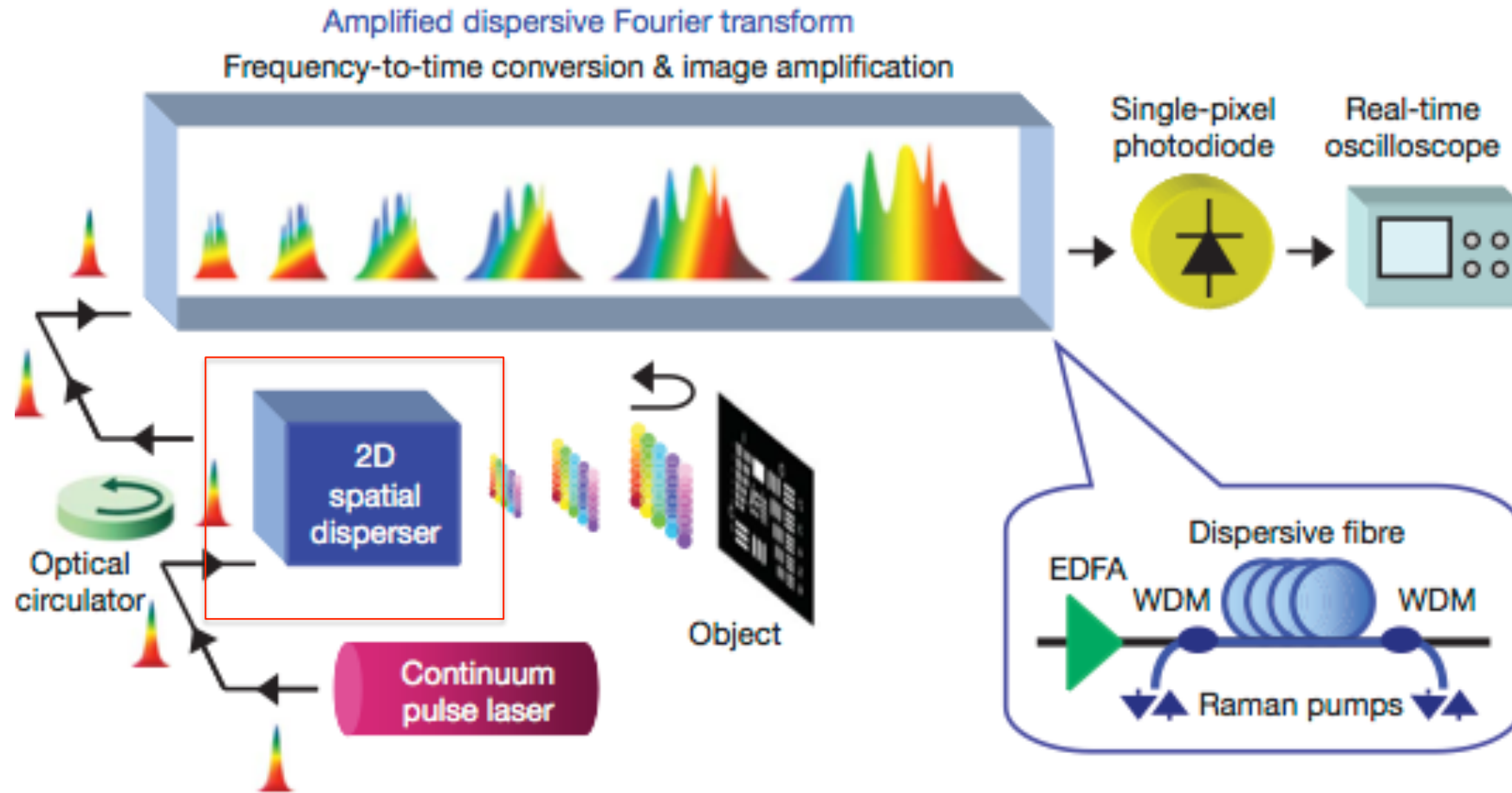
# Broadband absorption spectrum of a gas mixture (CH<sub>4</sub> and H<sub>2</sub>O)



- Average of 1000 wavelength sweeps
- Total acquisition time: 0.9ms

Spectral resolution: 39pm

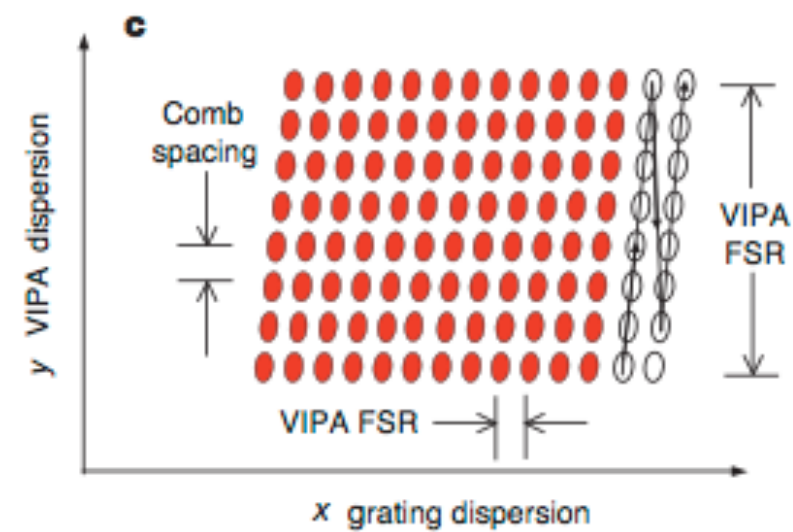
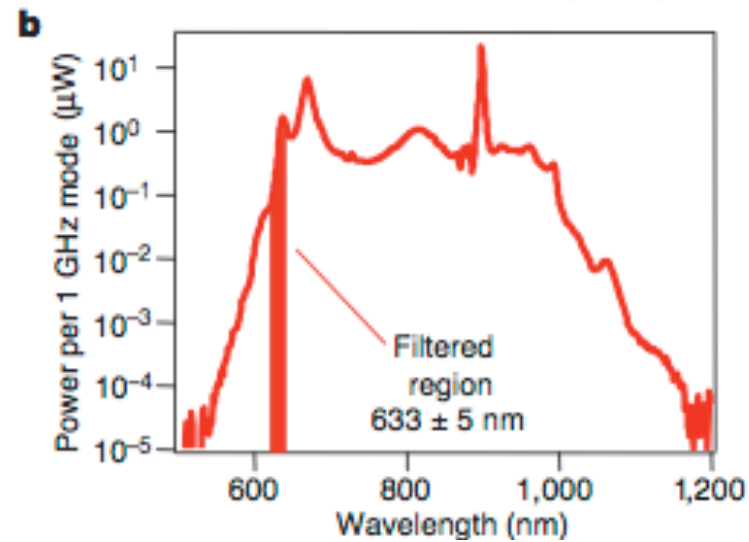
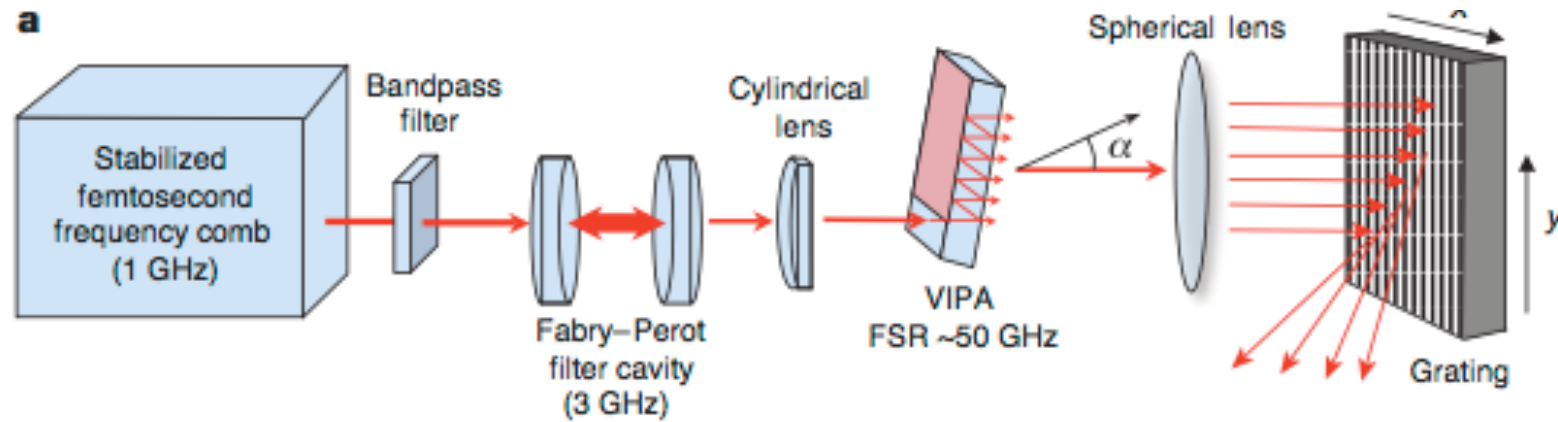
# STEAM camera



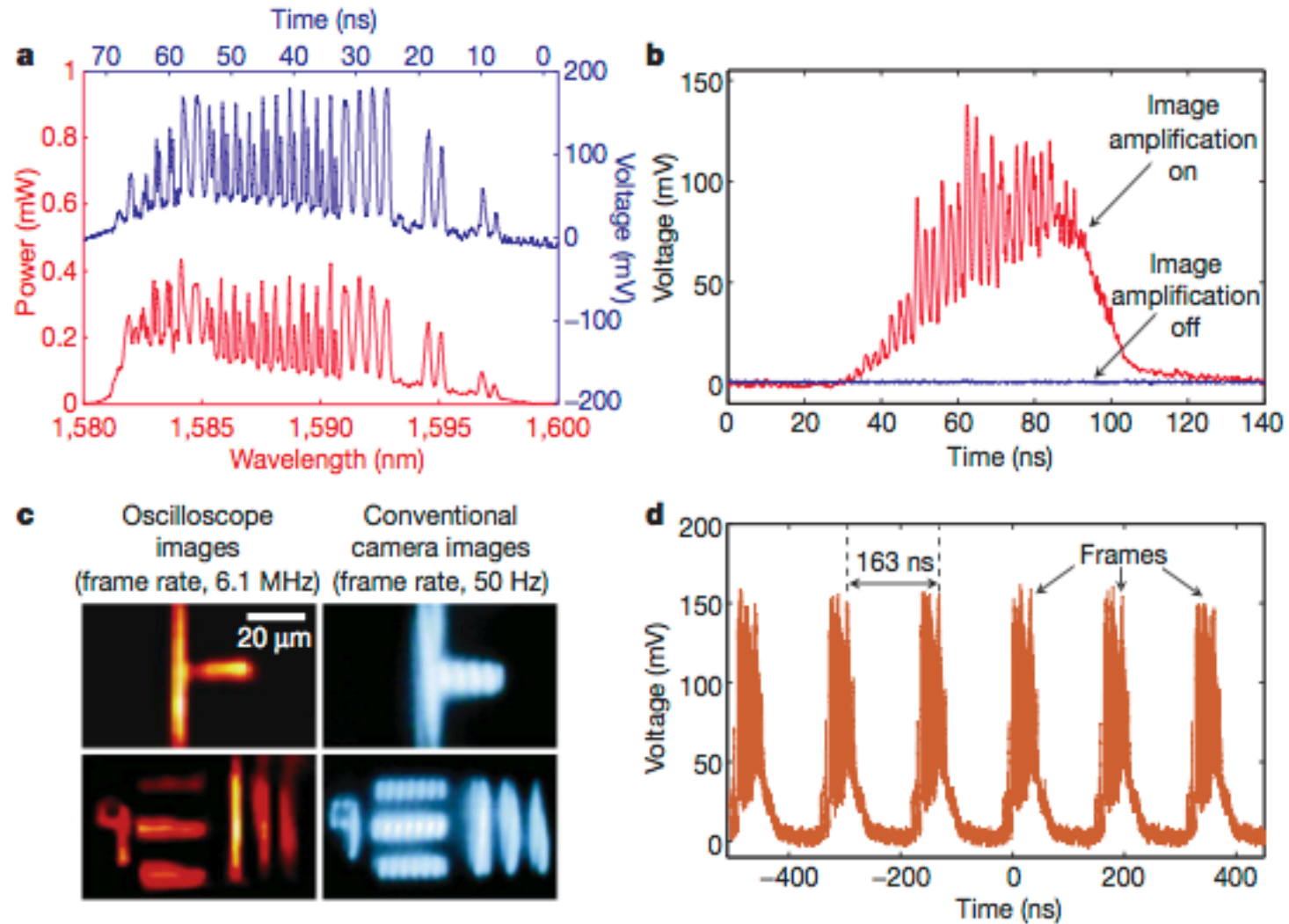
Ref: K. Goda, et al. (2009) *Nature*, 458: 1145.



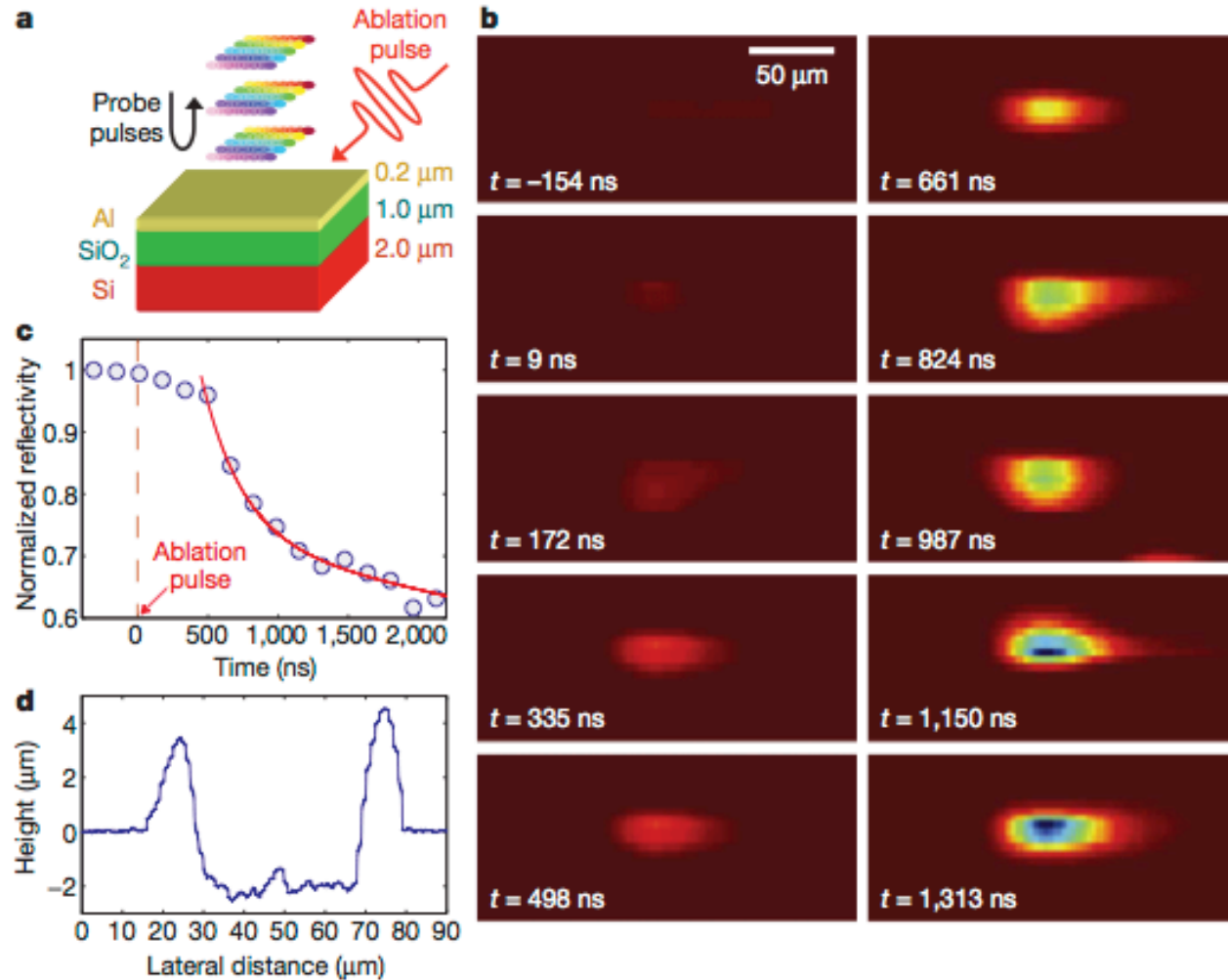
# 2D spatial disperser



# Basic operation of the STEAM camera.

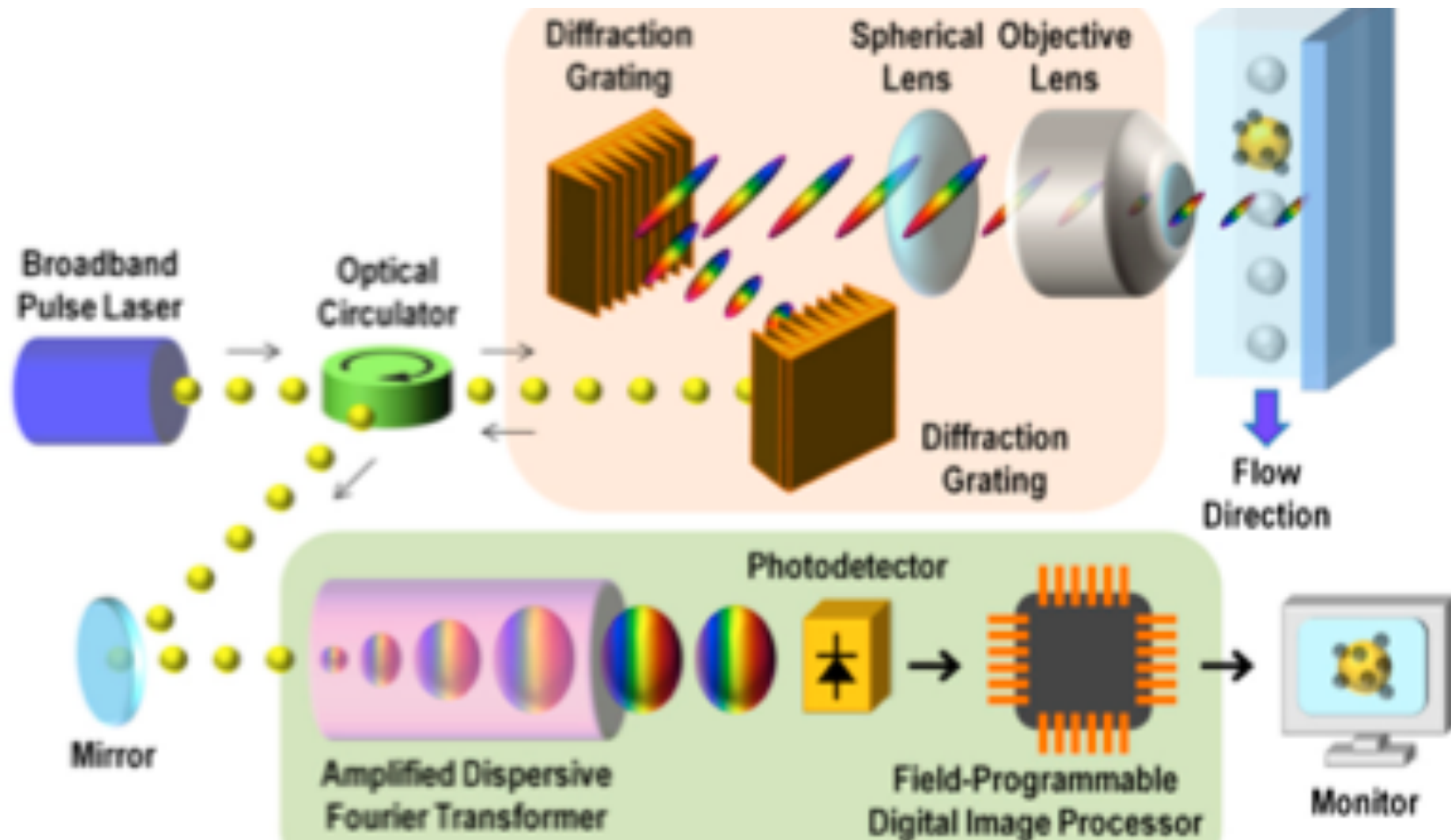


# The laser ablation experiment



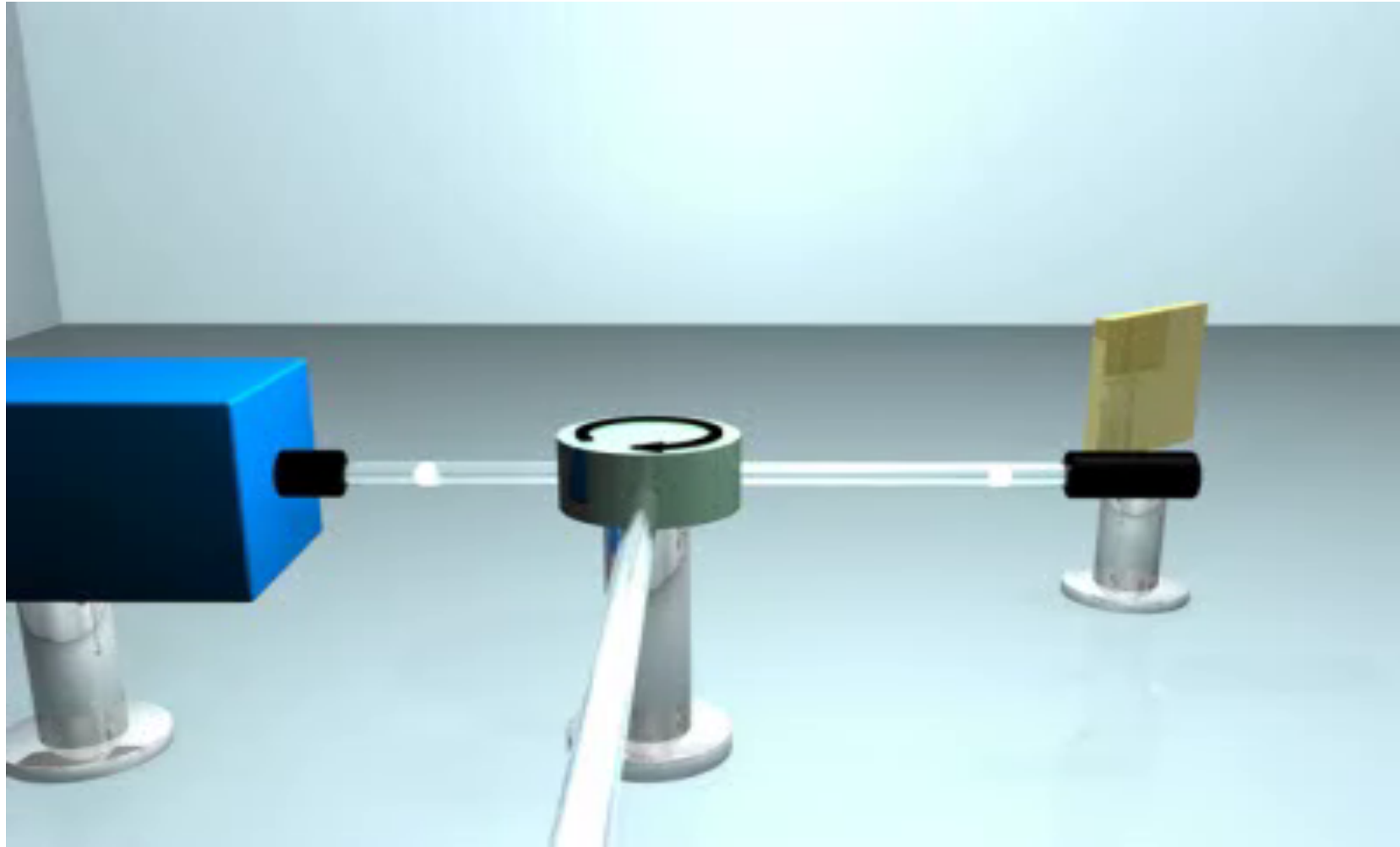
Temporal resolution: 163ns

# High-throughput single-microparticle imaging flow analyzer

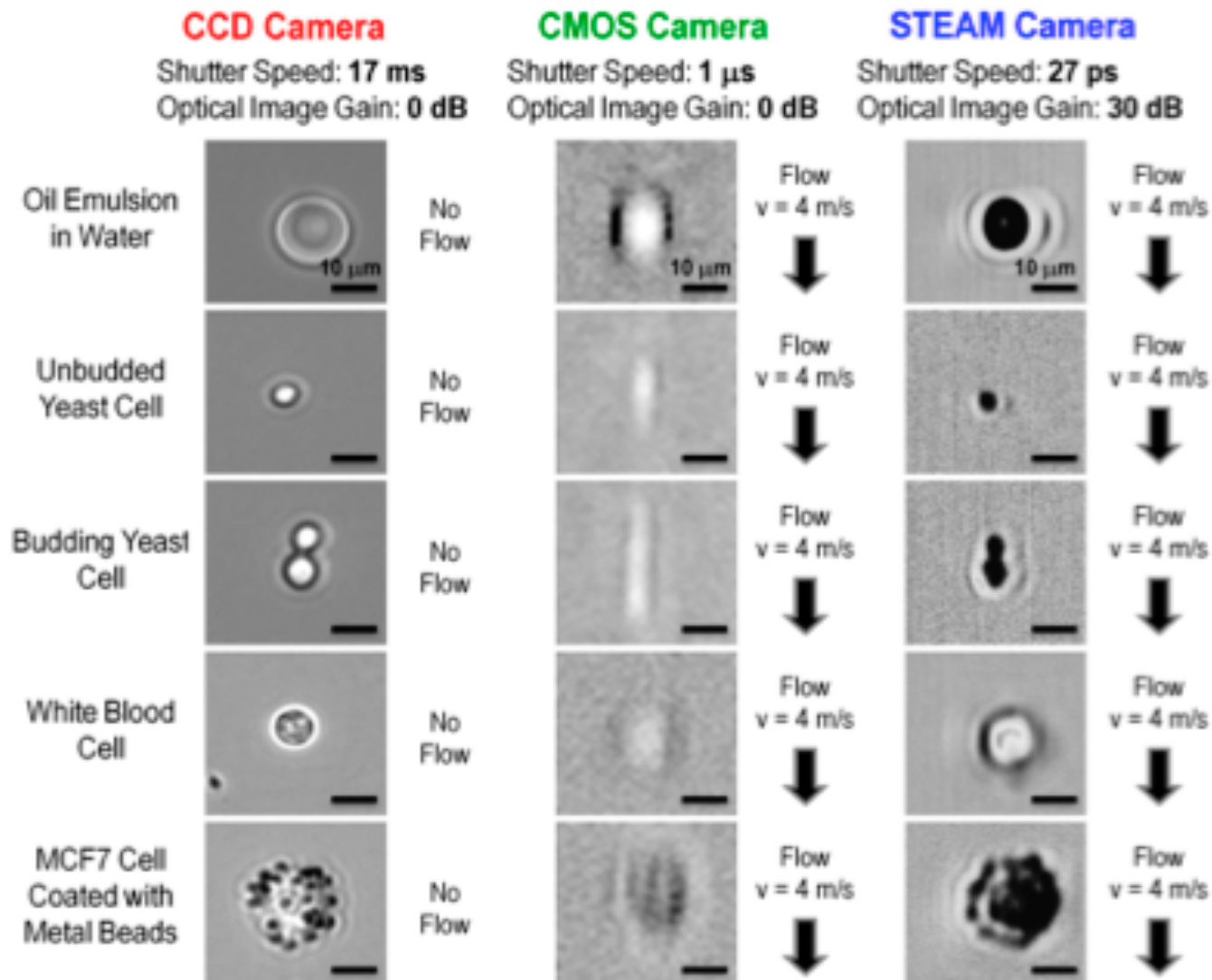


*Ref: K. Goda, et al. (2012) Proc. Natl. Acad. Sci., 109: 11630.*

# High-throughput single-microparticle imaging flow analyzer



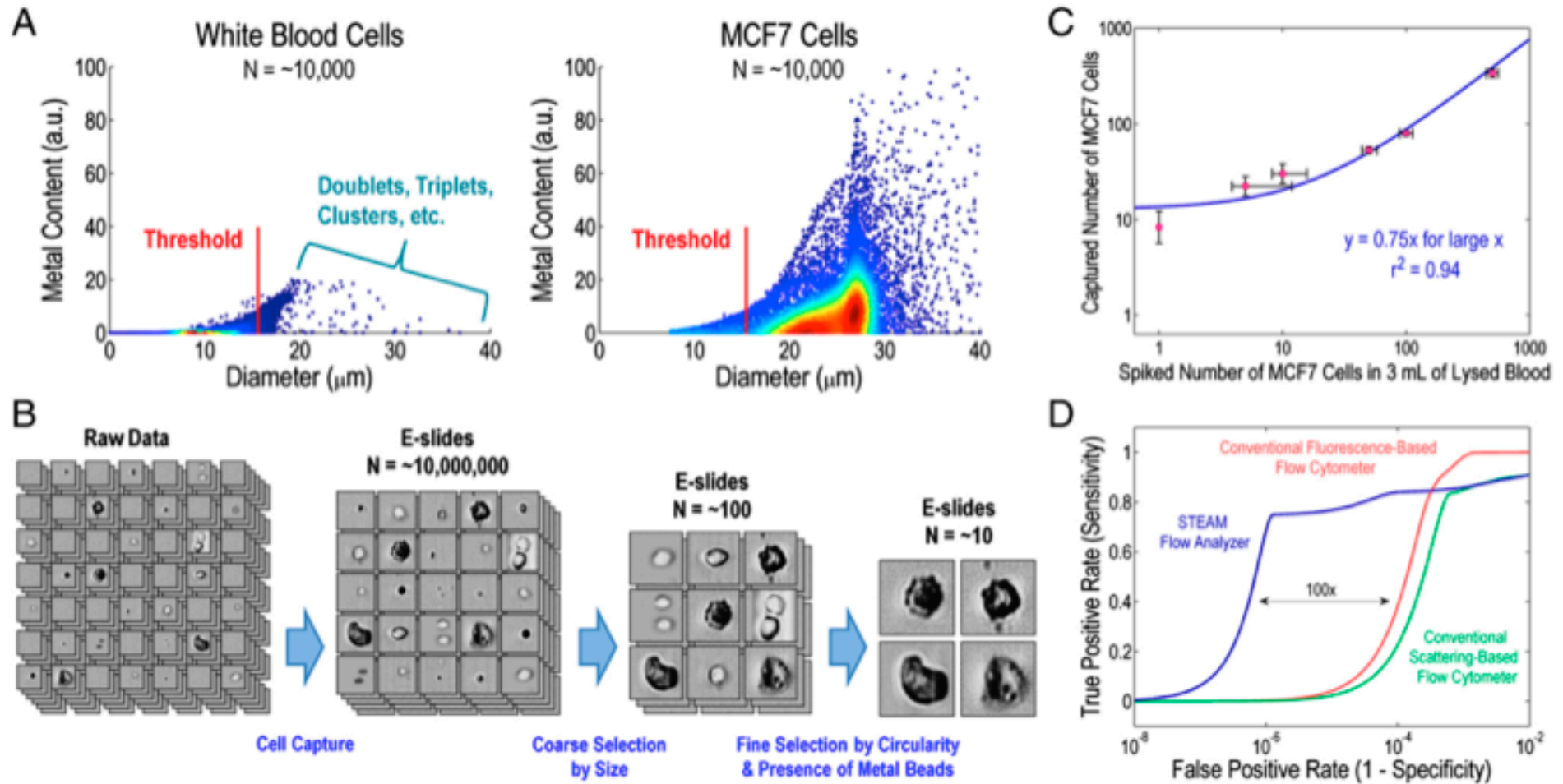
# Comparison with a conventional CCD camera and a CMOS camera



# Rare Cell Detection

- MCF7 (breast cancer cell) in blood
  - Red blood cells are lysed with a hypotonic lysing agent.
  - MCF7 cells are fixed with formaldehyde and coated with metal beads with a diameter of 1  $\mu\text{m}$  via an antibody to EpCAM

# Result



- Sensitivity: 75%
- 100,000 cells/s



# Summary

- High-speed instruments capable of capturing fast transient events are seeing increasing demand as the physical processes of interest become more complex.
- With its ability to perform fast continuous measurements, STEAM is expected to be useful for high-throughput screening and studying non-repetitive rare phenomena.