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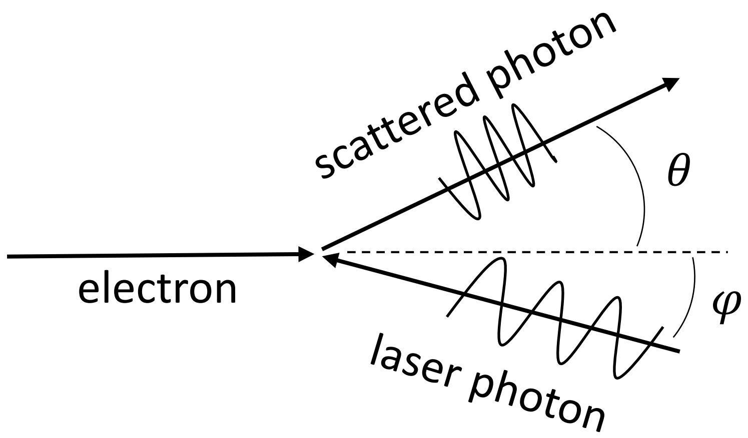
Optical Cavity for high flux Inverse Compton X-ray Source

WANG Huan
Joint Ph.D student of
Accelarator Laboratory, Tsinghua University, Beijing, China
LAL, Université Paris-sud, Orsay, France

The 11th FCPPL workshop, Marseille

24th May, 2018

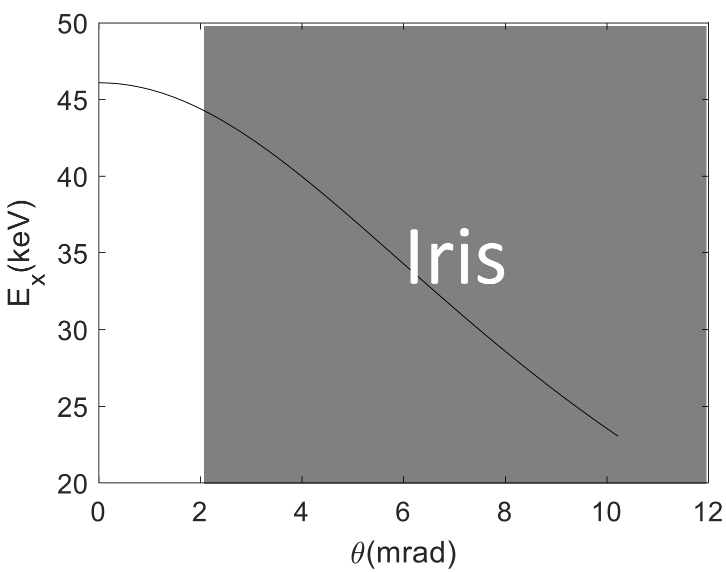
Inverse Compton Scattering



- **Powerful mechanism to boost photon**

For back scattered photon ($\varphi = 0, \theta = 0$)

$$E^{bs} \approx 4\gamma^2 E_L$$



50MeV electron, $\lambda = 1\mu m$ laser

- **Compact Light Source**

40keV X-rays from *50MeV* electrons

While Sychrotron and FEL needs *GeV* electrons

- **Quasi-monochromatic**

Inverse Compton Scattering

- **Small cross-section**

$$\sigma \cong 6.65 \times 10^{-29} m^2$$

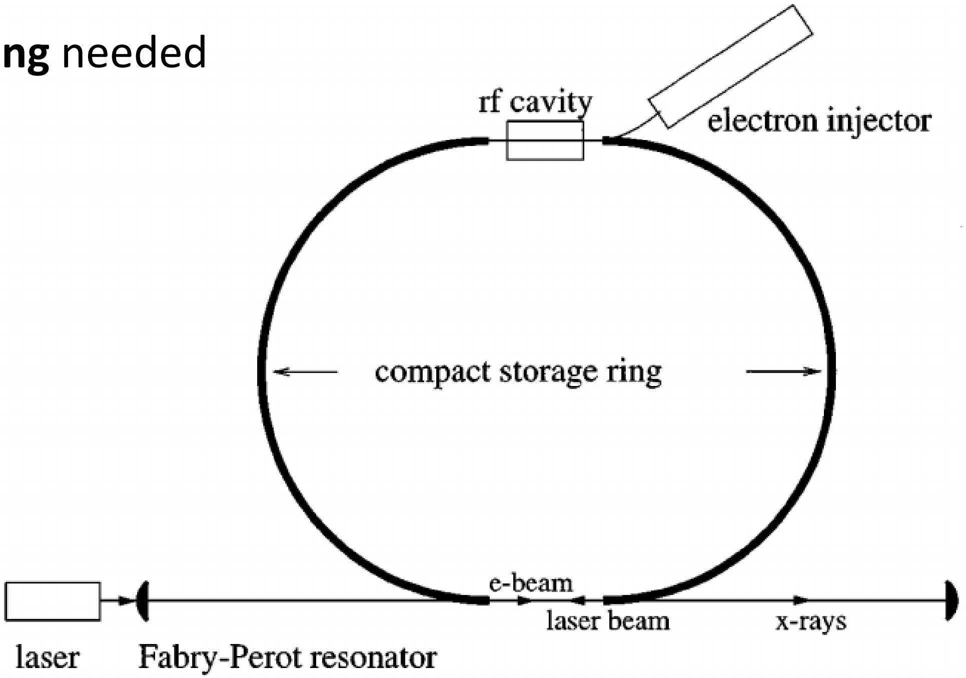
1nC electron, 500mJ laser → 10^6 /pulse X-ray

to increace the average flux of X-ray

Fabry-Perot cavity and **electron storage ring** needed

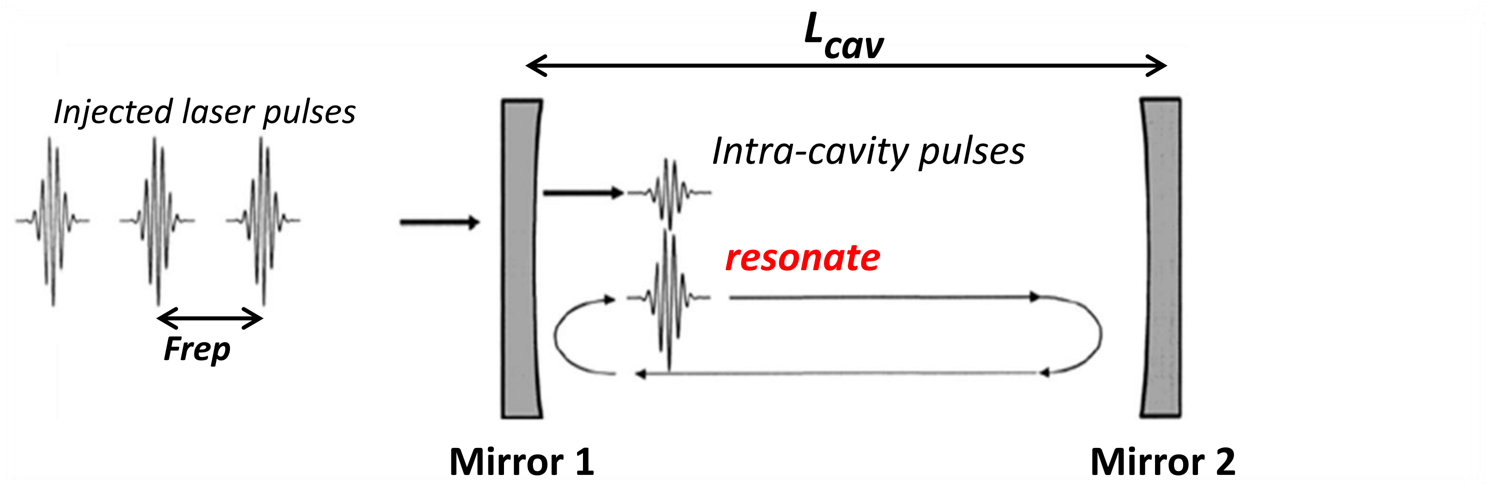
X-ray repetation rate $\sim 10MHz$

flux $\sim 10^{12} photons/second$

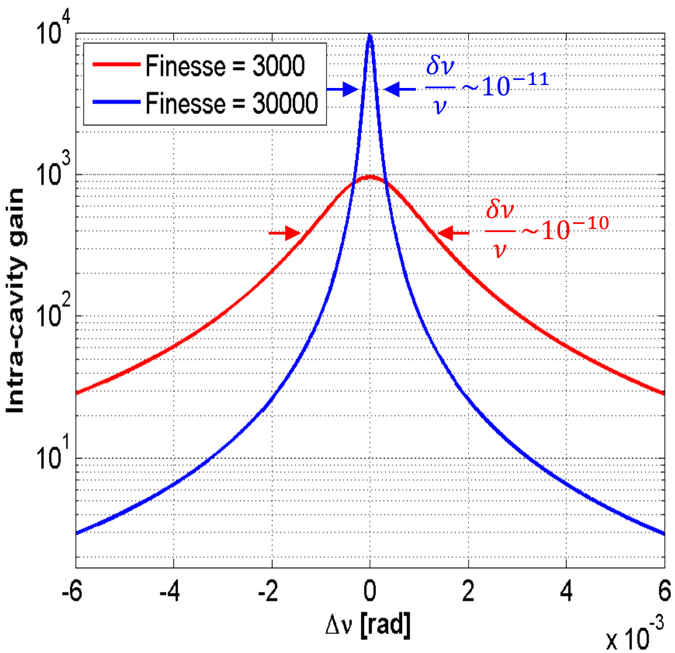


Physical review letters 80.5 (1998): 976.

Fabry-Perot cavity



- **resonator**, laser power stacked, $Gain \cong \frac{Finesse}{\pi}$
- **high repetition rate**, ~10MHz, cavity size ~few meters
- high demand for **feedback electronics**



TTX (Tsinghua Thomson X-ray source)

TTX

- 45MeV Linac
- 1nC
- 800nm laser
- pulse energy ~500mJ
- pulse length ~50fs
- flux ~10^6/pulse

update to **TTX2**

- Optical cavity
- Electron storage ring

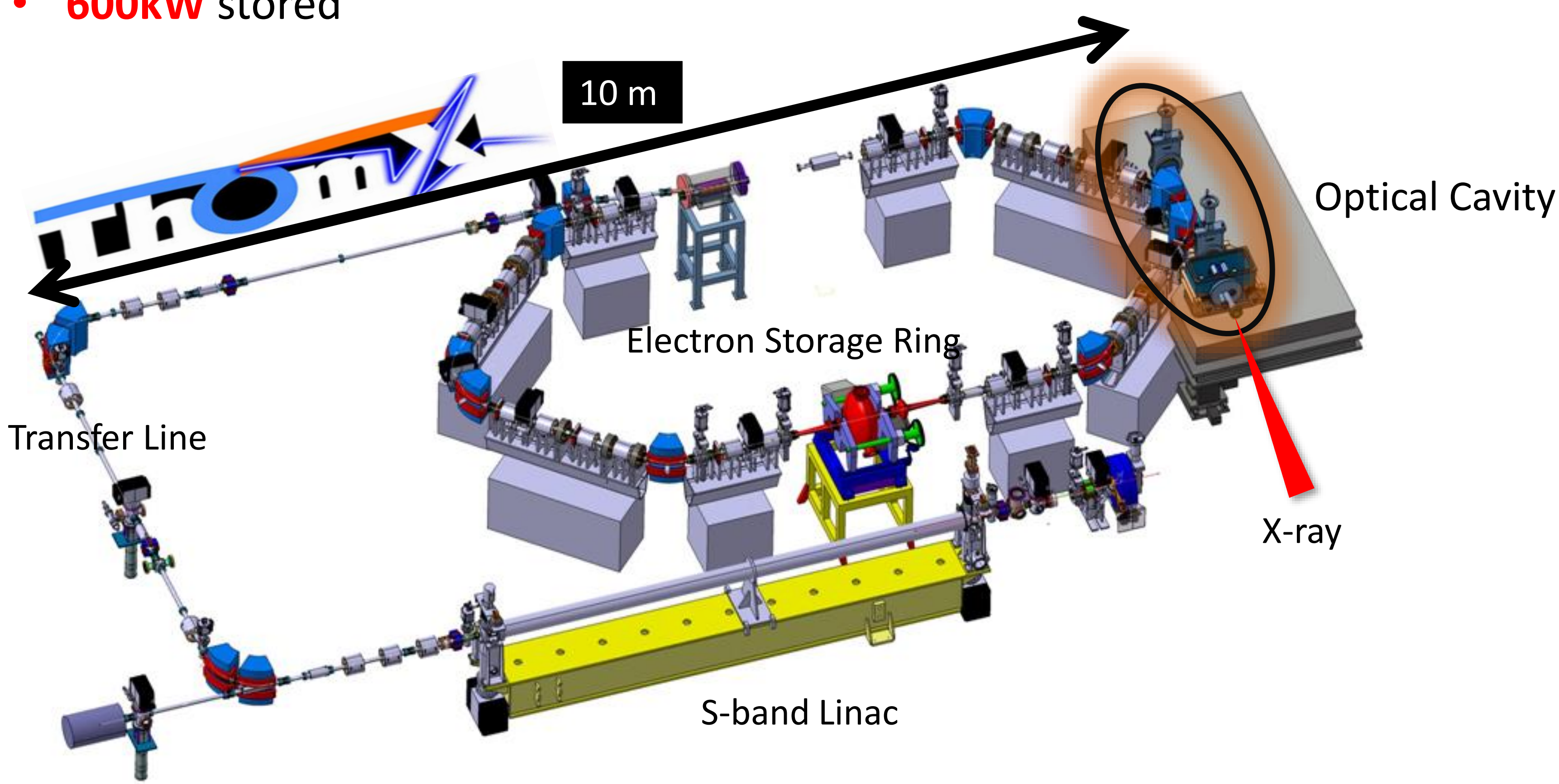
collaborating with LAL

ThomX project (at LAL)

- 50-70MeV
- 1 nC
- 1030nm laser
- 10k gain
- **600kW** stored

- flux **10^{11} – 10^{13}** ph/s
- 16.7 MHz
- energy cut-off **46-90keV**

Applications:
- Radiography
- Radiotheraphy
- Crystallograhy



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ThomX progressing photos

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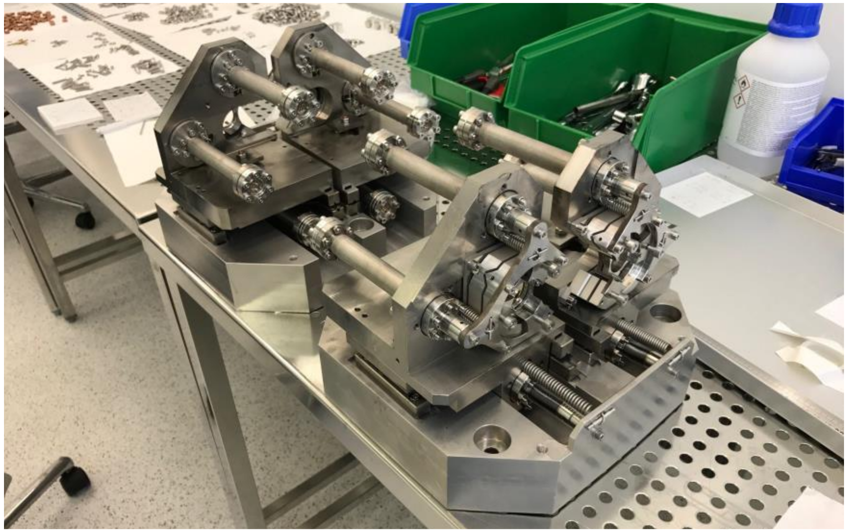

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R&D cavity

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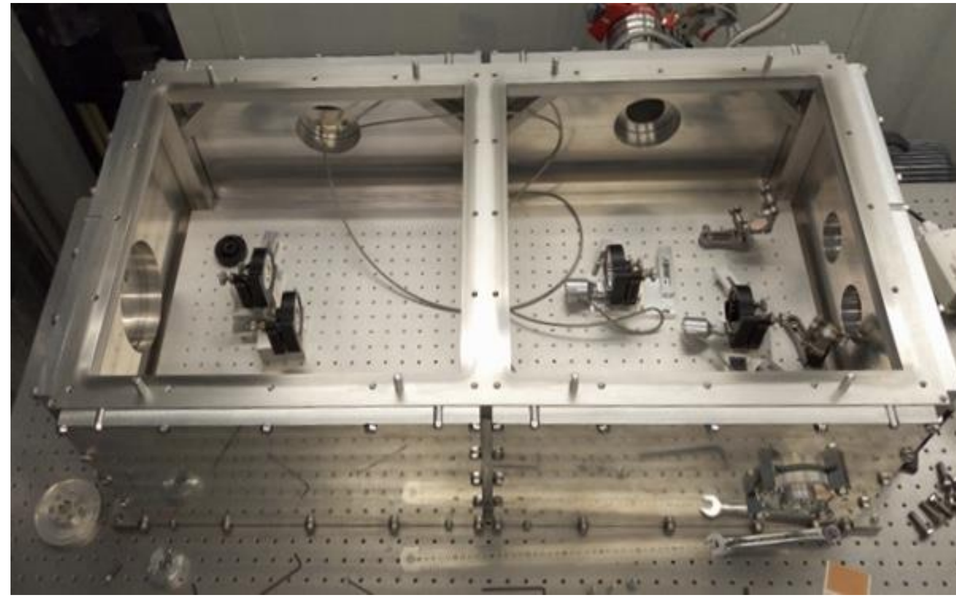
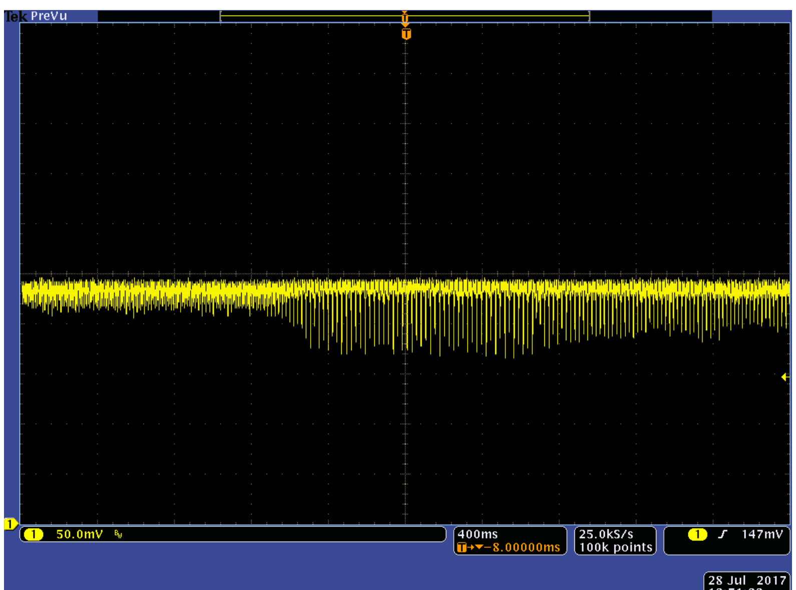
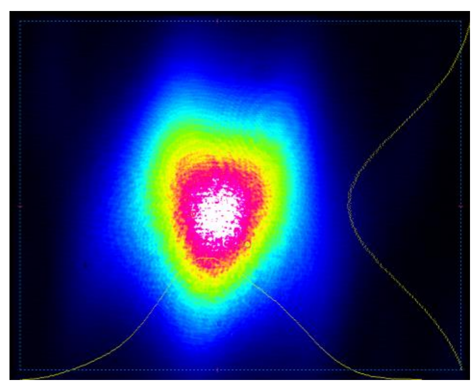
- Cavity length/ Freq = 2.25m/ 133.33MHz
- Finesse ~ 25000
- laser wavelength = 1030nm
- Input laser power = 40W





cavity transmission intensity on oscilloscope



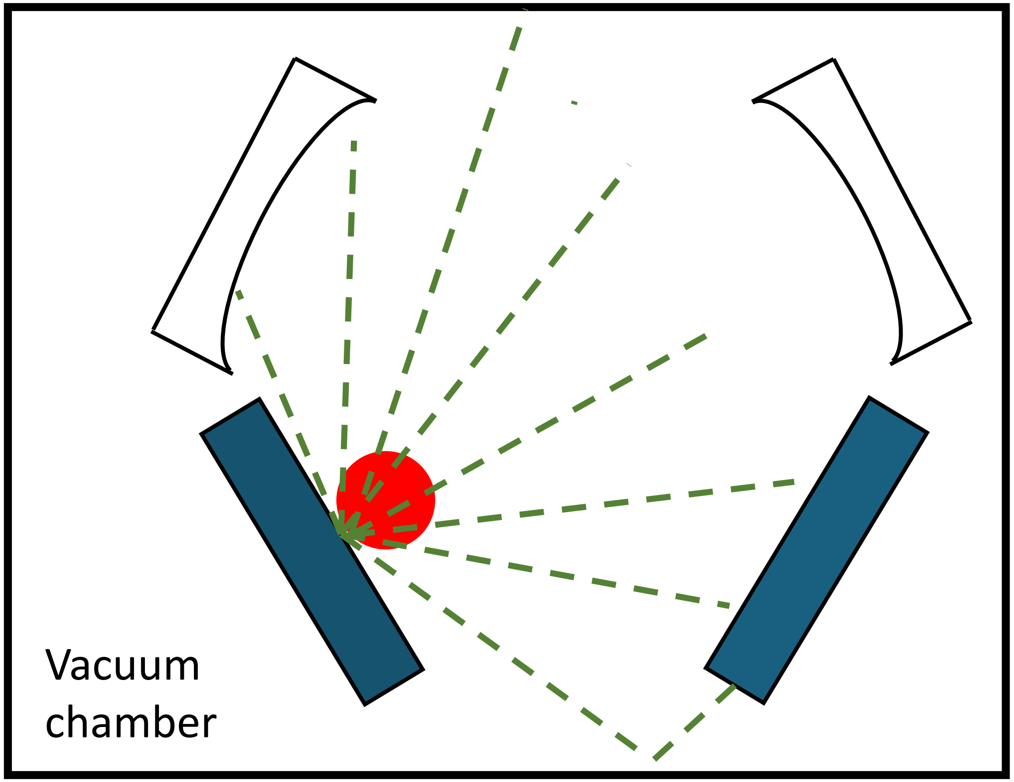
at 70kW of stacked power

Main issue: thermal effect

- Limit coupling
- Limit feedback system
- Limit stacked power

- lose locking

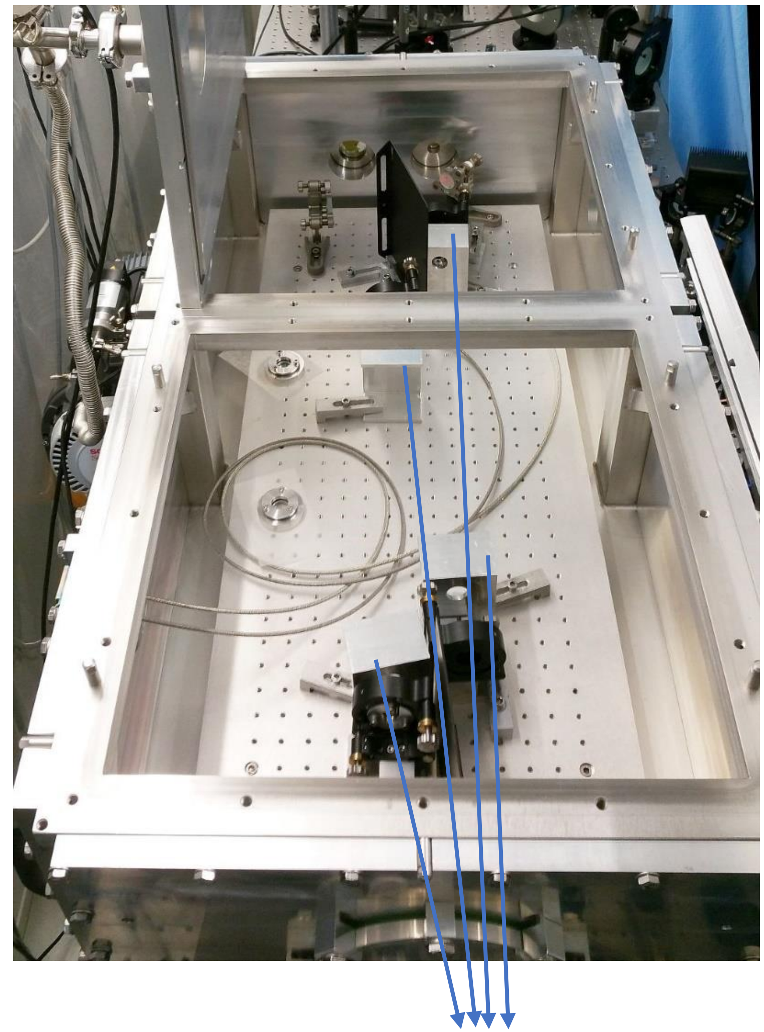
Thermal Effect



hypothesis:

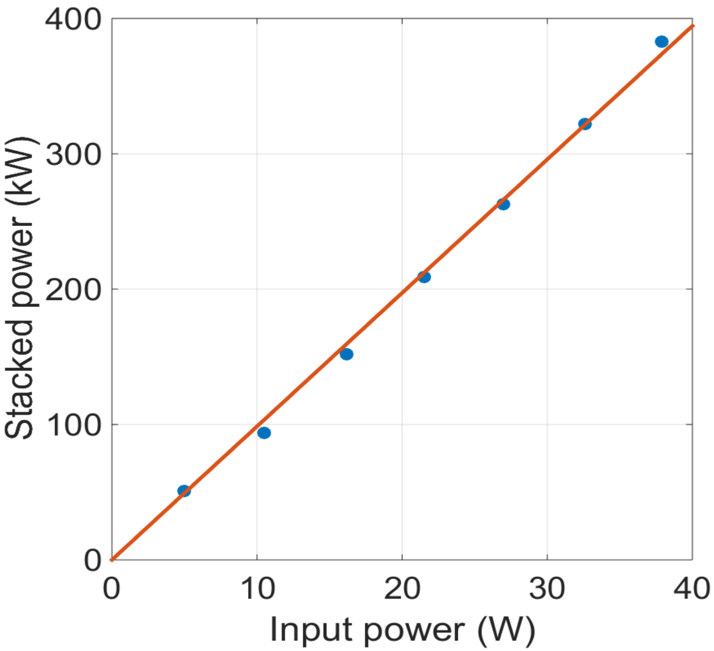
scattering light heating mirror mount

- optical axis changes
- coupling to high order mode



masks added in front of mirror mounts

R&D cavity



- Max stacked power ~**400kW** (few minutes)
- Highest stored power for high finesse regime cavity
- 670kW achieved with 1/10 x gain and 10 x input power*

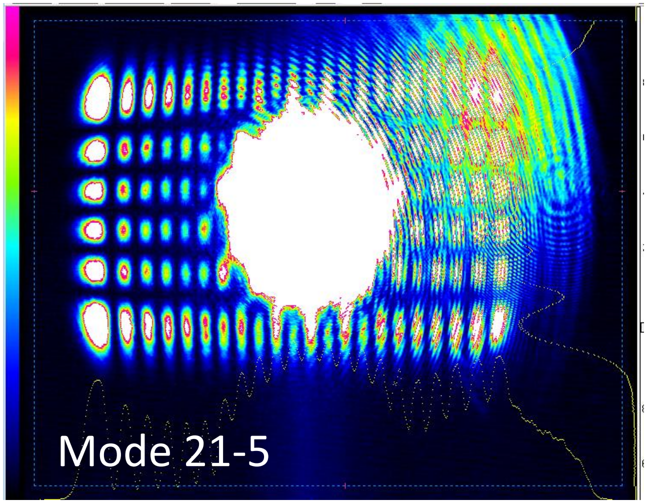
- Effective enhancement factor ~ ***10 000***
- Spatial coupling ~ ***90 %***

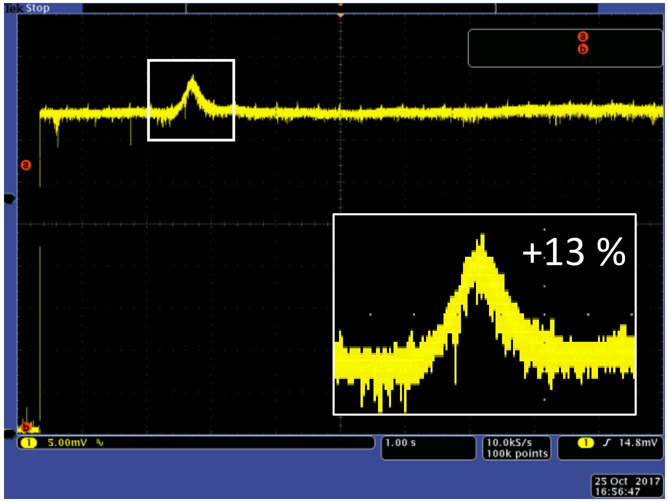
- Thorough re-alignement at every step
- Still limited by **thermal effects**

**Optics letters*39.9 (2014): 2595-2598.

Low power – mode degeneracy

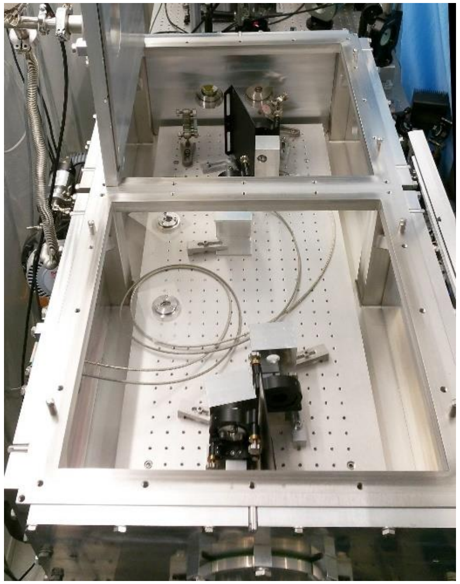
- Low input power (100 mW)
- CW laser beam





- Max coupling ~ $\frac{1}{2\pi\sqrt{mn}}$ < 2 % (extremely misaligned system)
- There must be something else than mount heating

Works to do



R&D cavity

- Understand thermal misalignment of the optical axis
  - Find a way to avoid/limit it
- Understand mode instabilities
  - Dynamical model (Finesse software from LIGO)
  - Experiments
  - Find a way to control it

ThomX cavity

- Laser, optics control & locking systems
- Install the CELIA high power amplifer
- Test high power regime & long term stability
- Install the system in the ThomX accelerator (end 2018)

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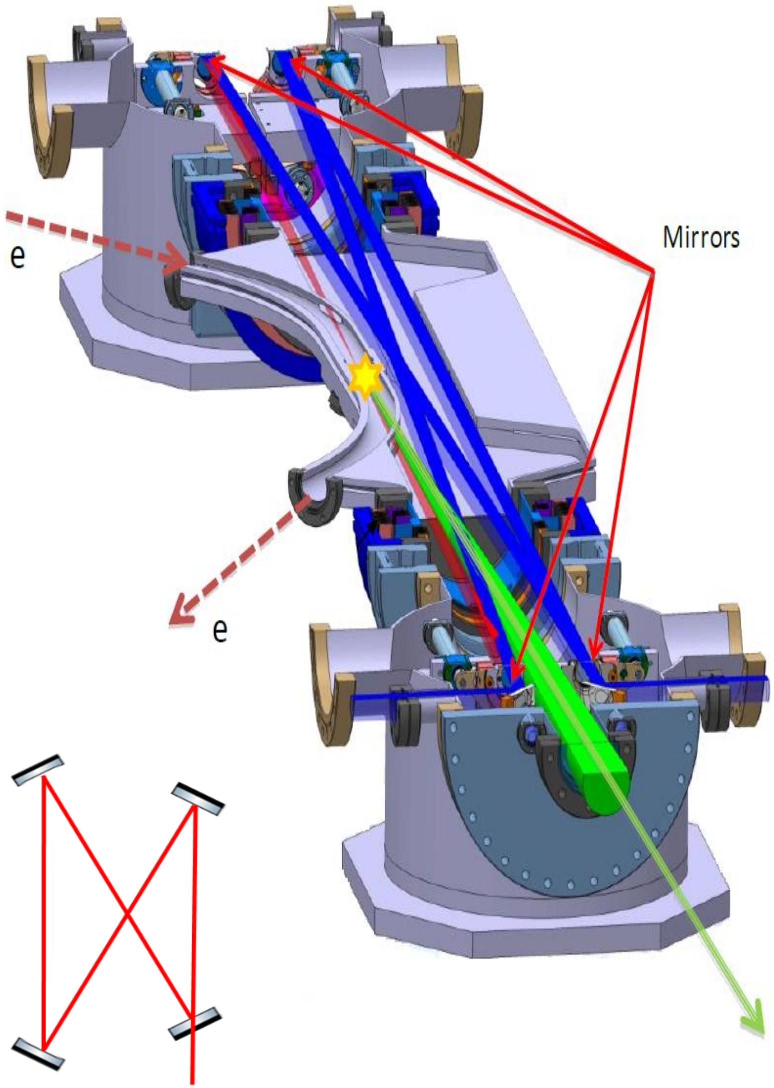
ThomX Optical cavity



- laser wavelength = 1030nm
- Input laser power = 100W
- Laser pulse length ~1ps

- Cavity length/ Freq = 9m/ 33.33MHz
- Finesse = 42000
- Gain(design) = 22000
- Gain(needed) = 6000
- Stacked power = **600kW**

- Laser beam size @IP = 100μm