Optical R&D for laser beam – electron beam Compton scattering technology and applications

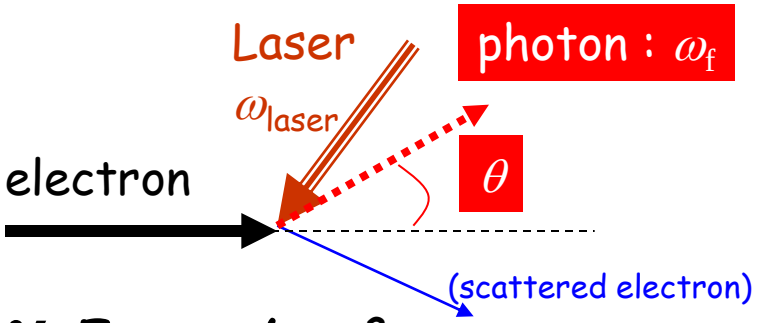
I. Interests in Compton sources
   - ➔ Positron source
   - ➔ Compact X-ray machine

II. Research & Development
   - ➔ Fabry-Perot optical cavity
   - ➔ Fiber-based Chirped Pulses Amplification

III. Achievements

IV. Work in progress

Compton scattering



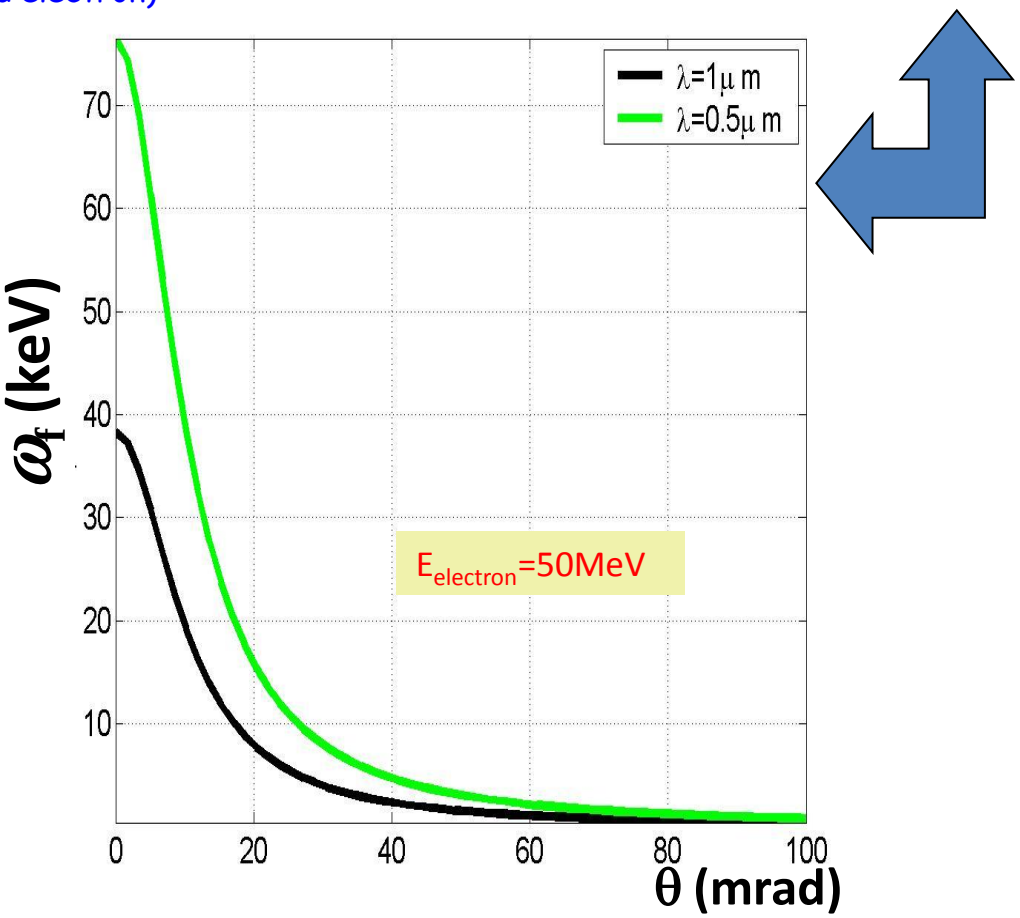
$\gamma = E_{electron}/m_e c^2$

Compton scattering

Photon_laser+e→photon+e'

is a

2 body process ➔ $\omega_f = f(\theta)$



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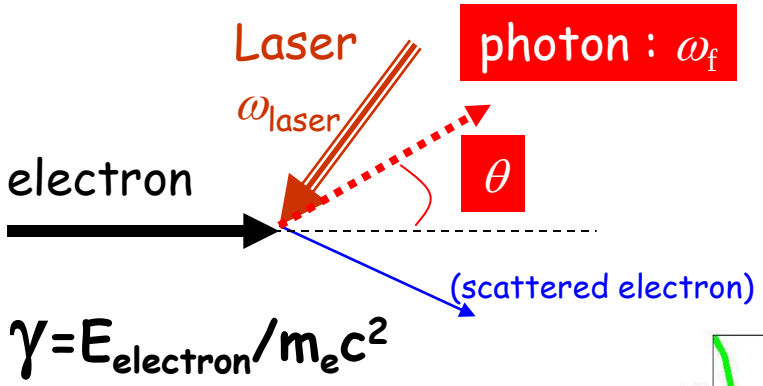

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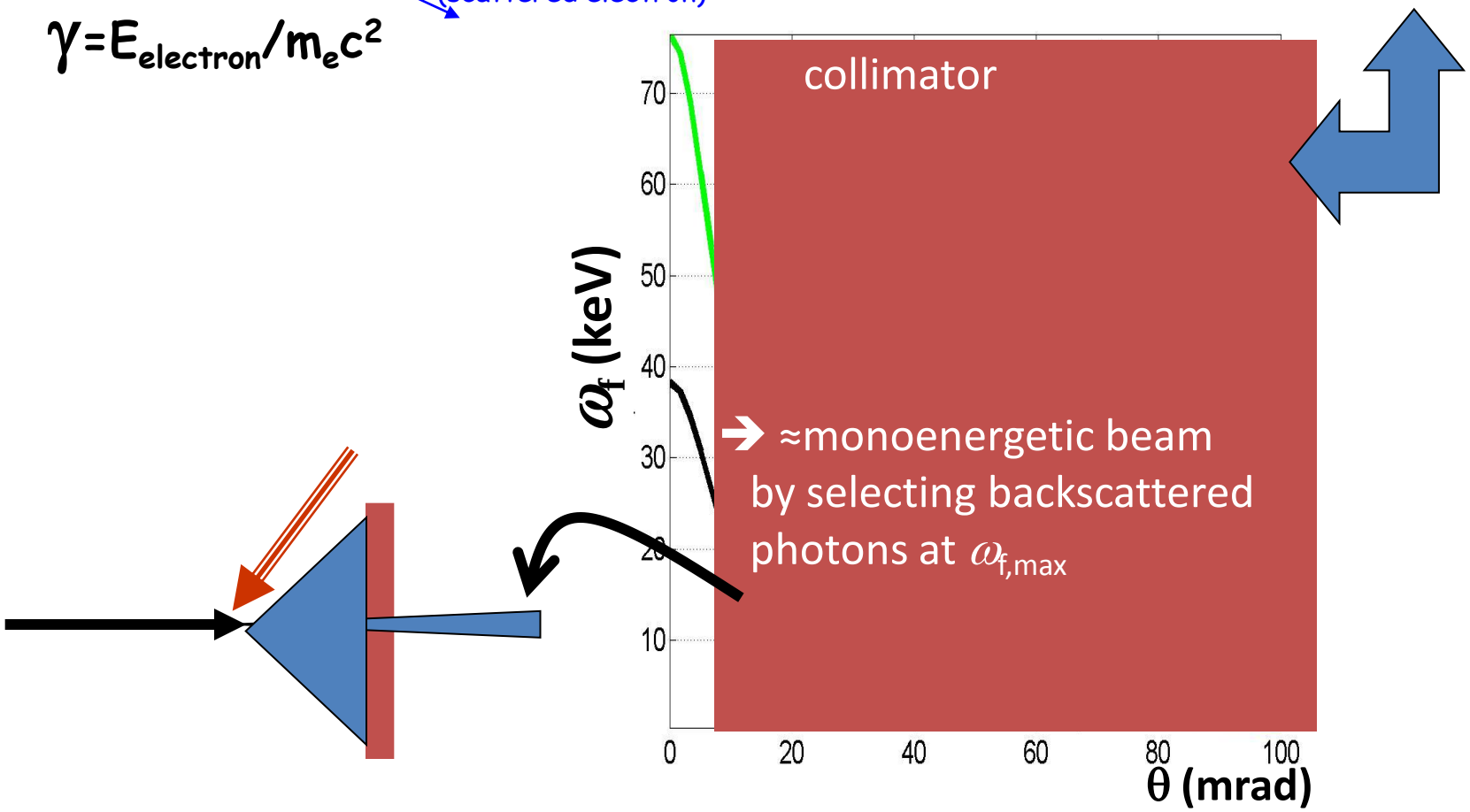
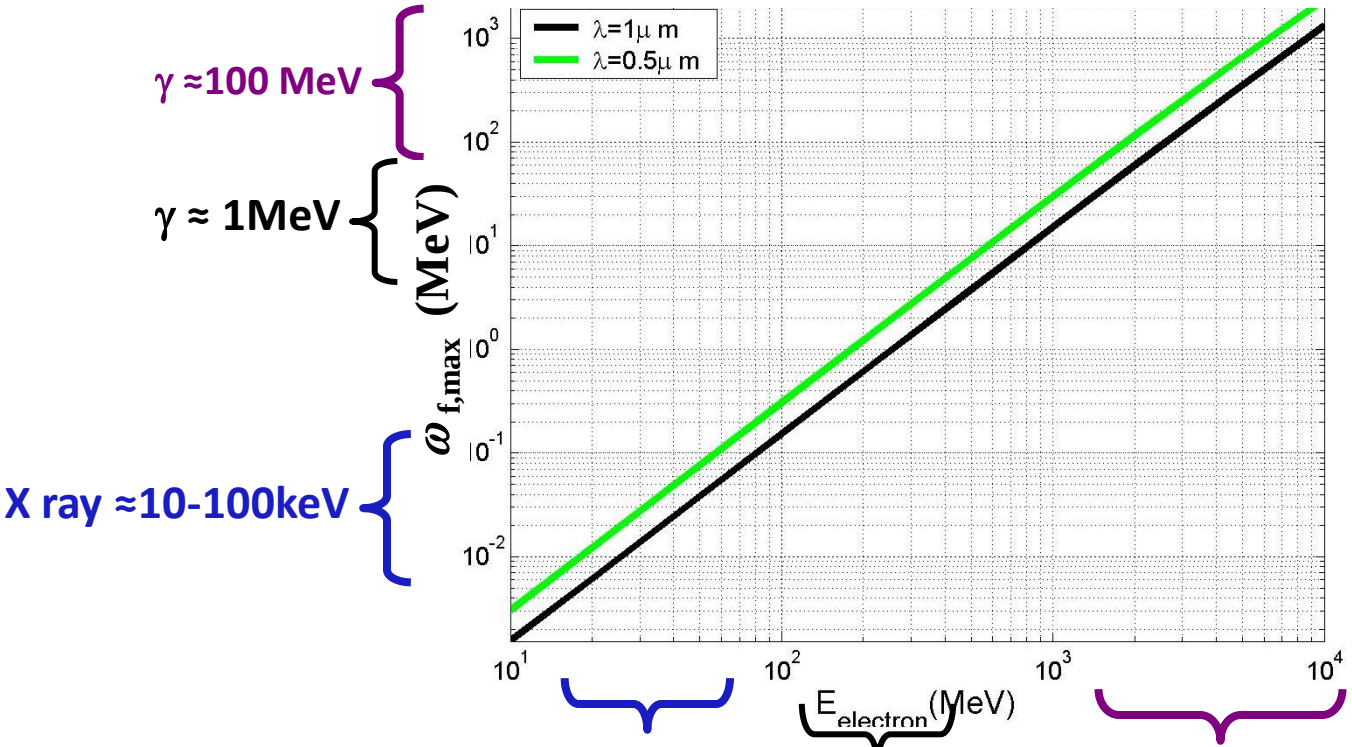


Application of Compton scattering



Low energy applications

- Medical: radiography &radiotherapy
- Museology
- Material science
- crystallography

Nuclear fluorescence applications

- Nuclear survey
- Nuclear waste management

High energy applications

- Compton polarimeter
  ➔LEP energy measurement
- Laser wire
- γγ collider
- Polarised positron source

Motivation for a compact Compton X-ray source

Studies that have been done with synchrotron light that we would like to do in a museum, hospital or a laboratory room:

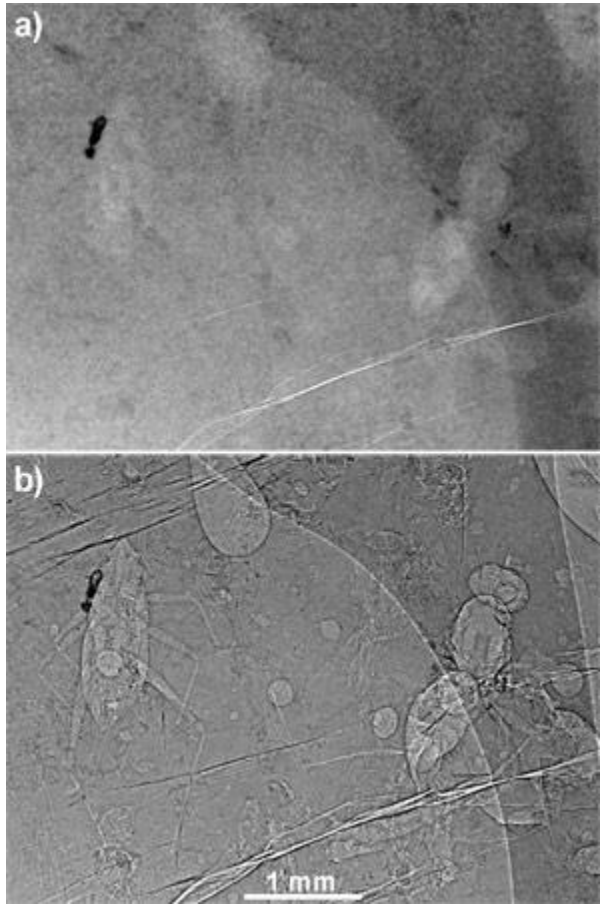
- Painting analysis
- Paleontologie
- …

Exemples taken from results at the ESRF Syncrotron machine (http://www.esrf.eu/news/spotlight/)

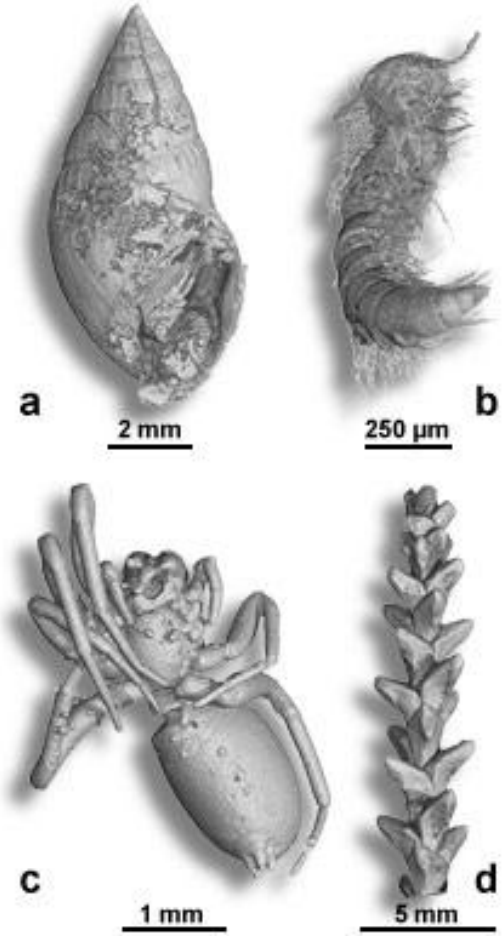
Paleontology application
(http://www.esrf.eu/news/general/amber/amber/)

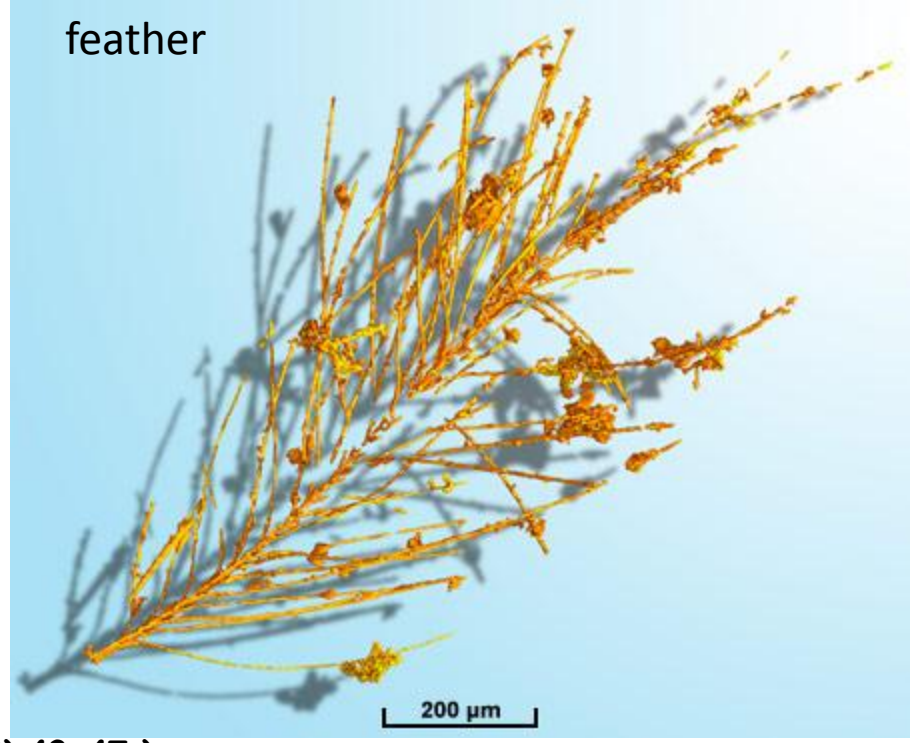
Piece of amber
100 millions years BC (France/Charentes)

≈30keV monochromatic X-rays from ESRF

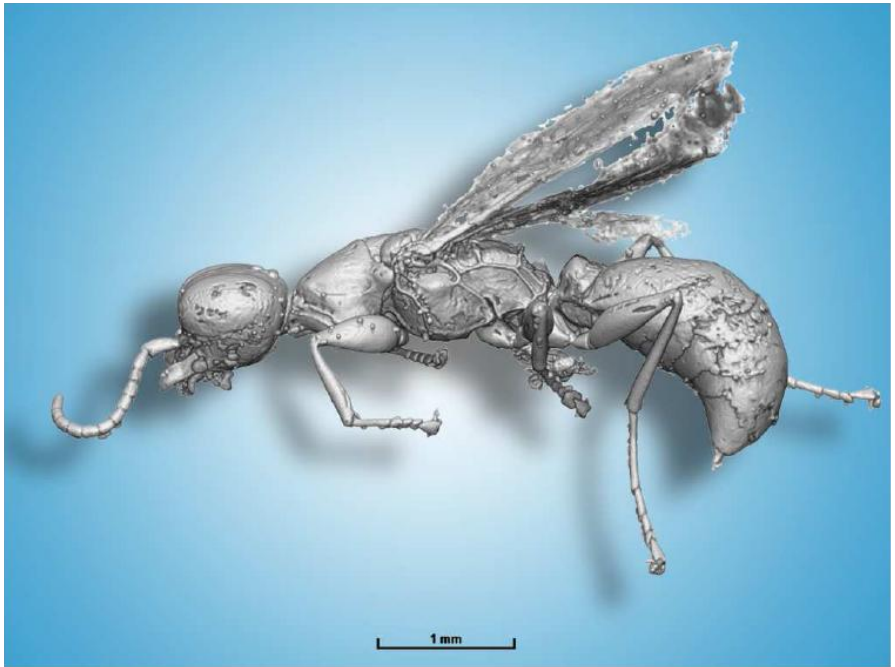


➔ non destructive 3D imaging
of elements contained inside the ambre since more than 100M years





(Synchrotron Rad. 16(2009) 43-47)

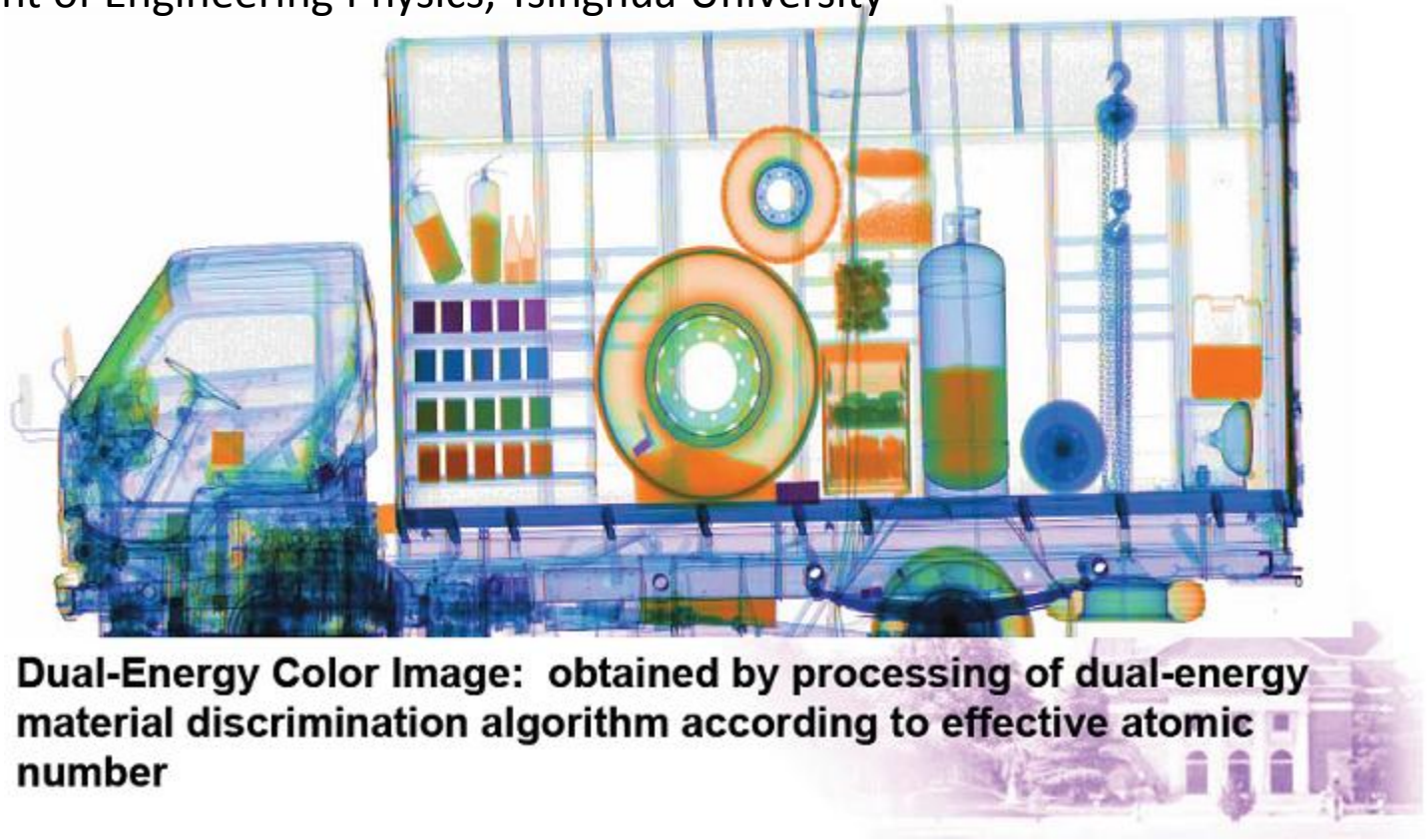


(Tafforeau, ESRF)

Tsinghua Thomson scattering X-ray source (TTX)

Image Example and Photo Dual-Energy Color Image of a Van with Different Tested Samples

Ch.X. Tang
Department of Engineering Physics, Tsinghua University



Dual-Energy Color Image: obtained by processing of dual-energy material discrimination algorithm according to effective atomic number

Technological issues

Laser beam/e^- Compton scattering prosses has very low cross section

➔Need of very high laser flux to have a significan X-ray flux
>10 MW needed for ILC/CLIC and ≈100-500 kW for low energy application
➔ Pluses stacking of high power laser in high finesse Fabry-Perot cavity is the best way to obtain high photon flux for the interaction

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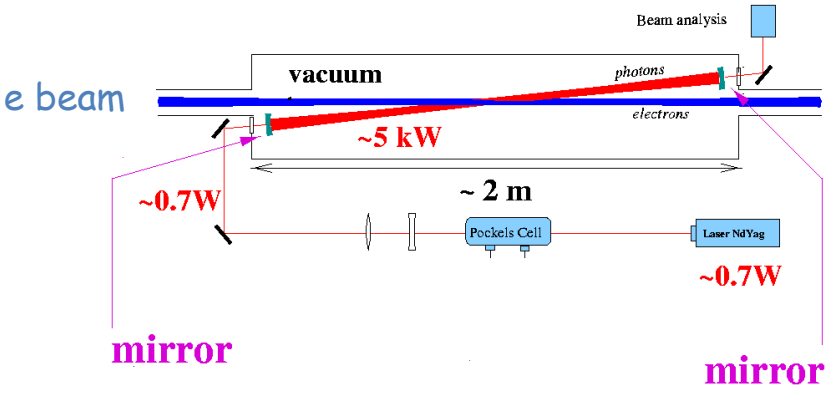
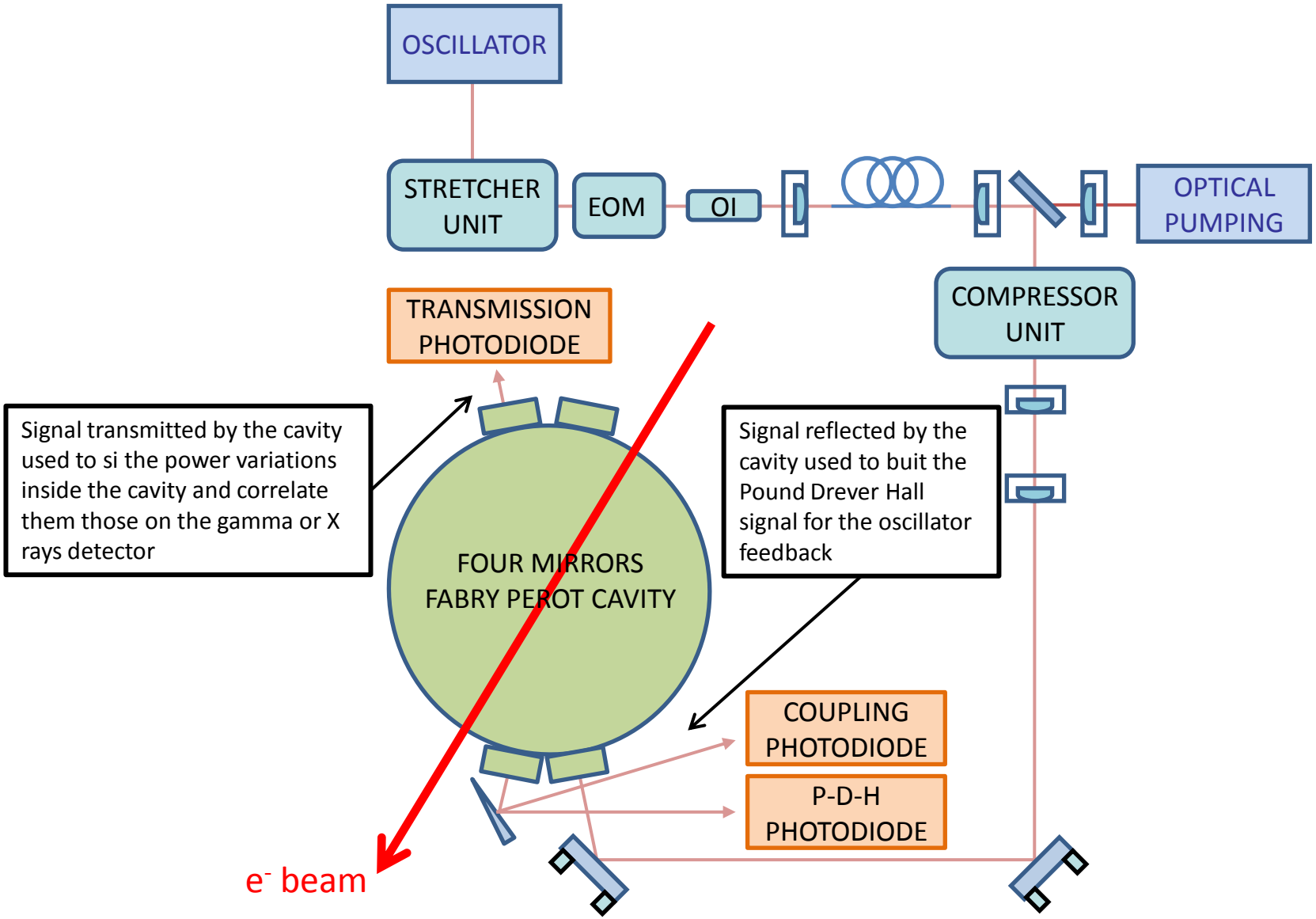


When $\nu_{Laser} \propto c/2L \Rightarrow$ **resonance**

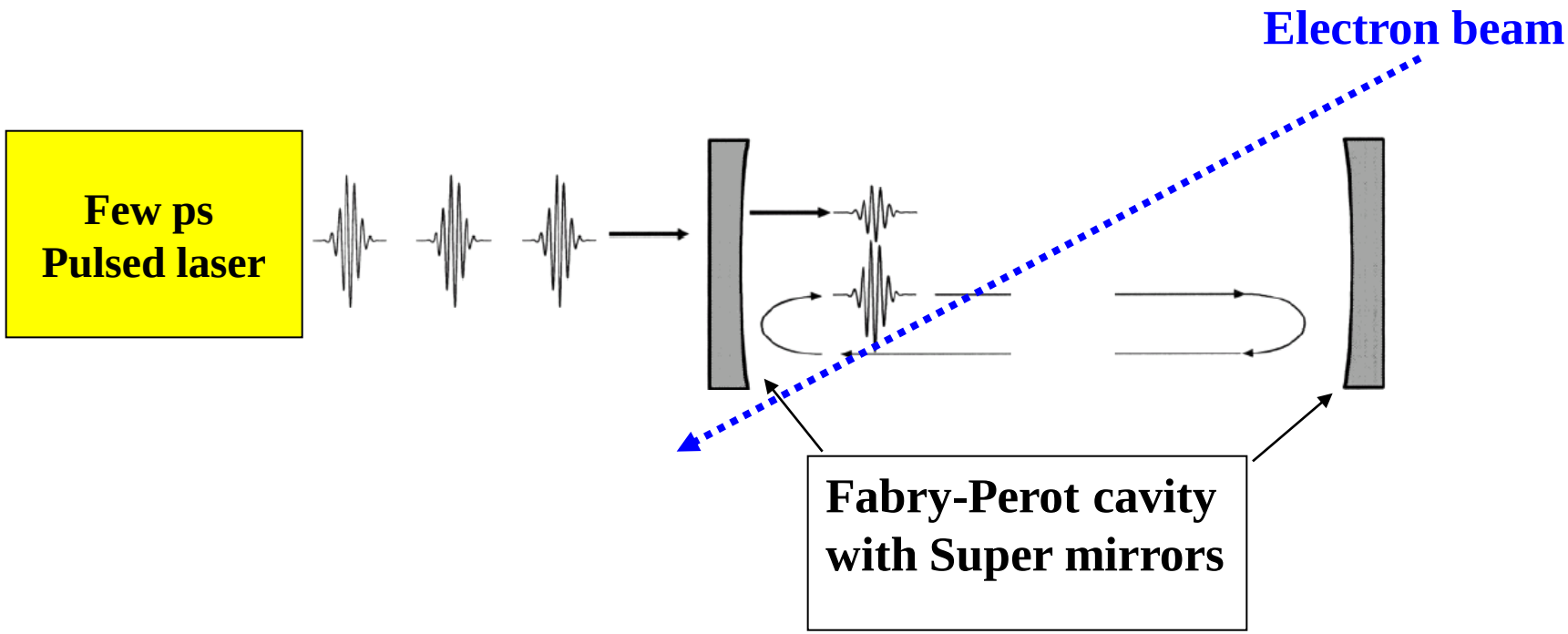
But: $\Delta\nu/\nu_{Laser} = 10^{-12}$

$\Rightarrow$ **STRONG & ROBUST laser/cavity feedback needed…**

Research & Development



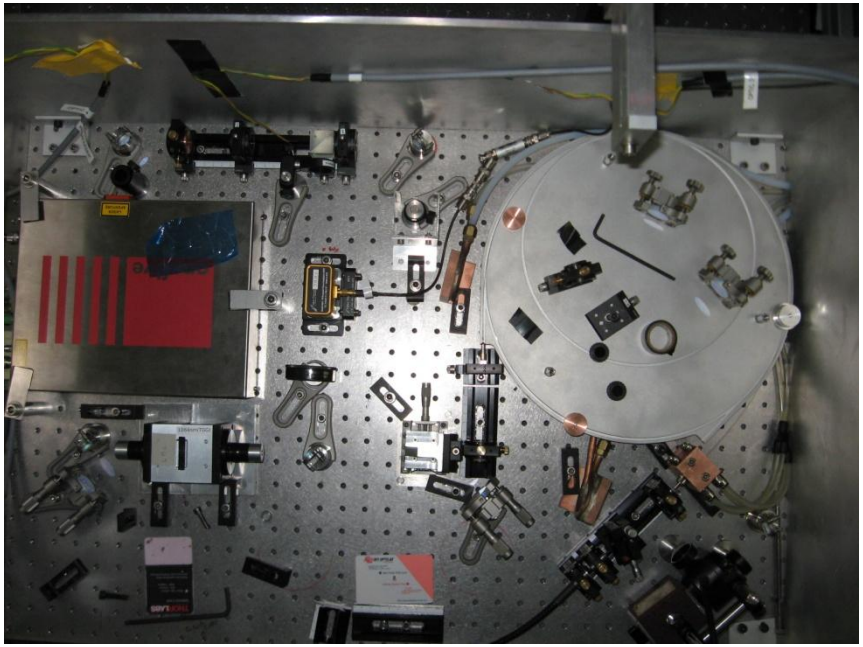
The Fabry-Perot cavity



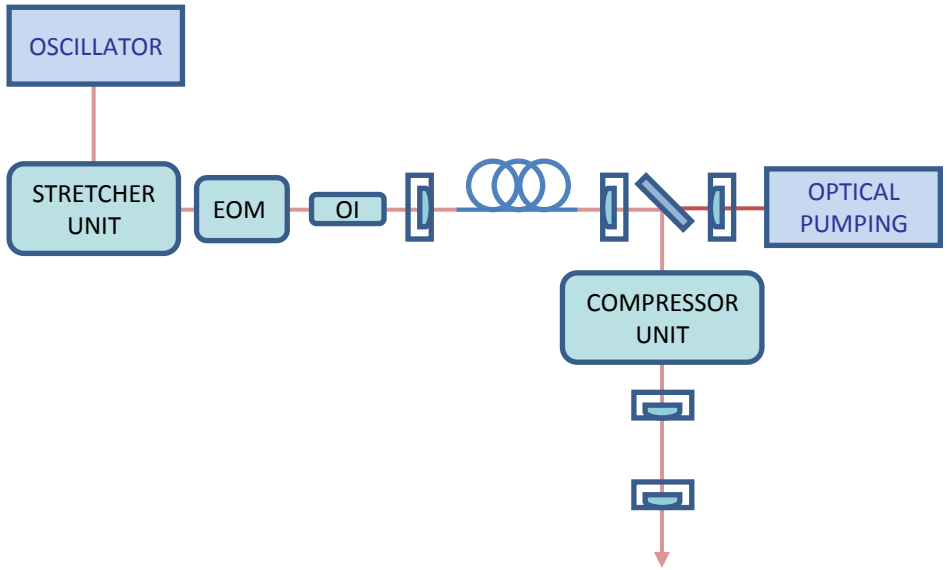
State of the art (Garching MPI) : **~70kW,** 2ps pulses @78MHz, stored in a cavity
(O.L.35(2010)2052) **~20kW,** 200fs pulses @78MHz

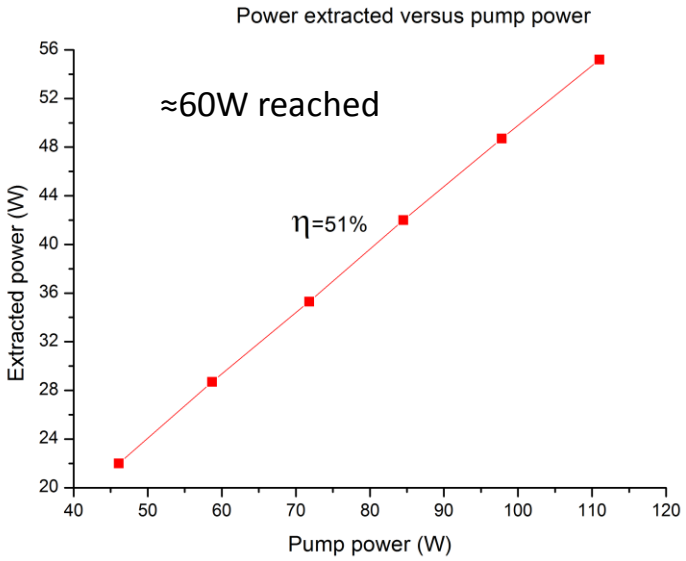
>10MW needed for ILC/CLIC ! ≈(100-500)kW for low energy applications
⇒ Important R&D is needed!

Fiber-based Chirped Pulses Amplification (FCPA)



Laser setup at ATF (february 2011)





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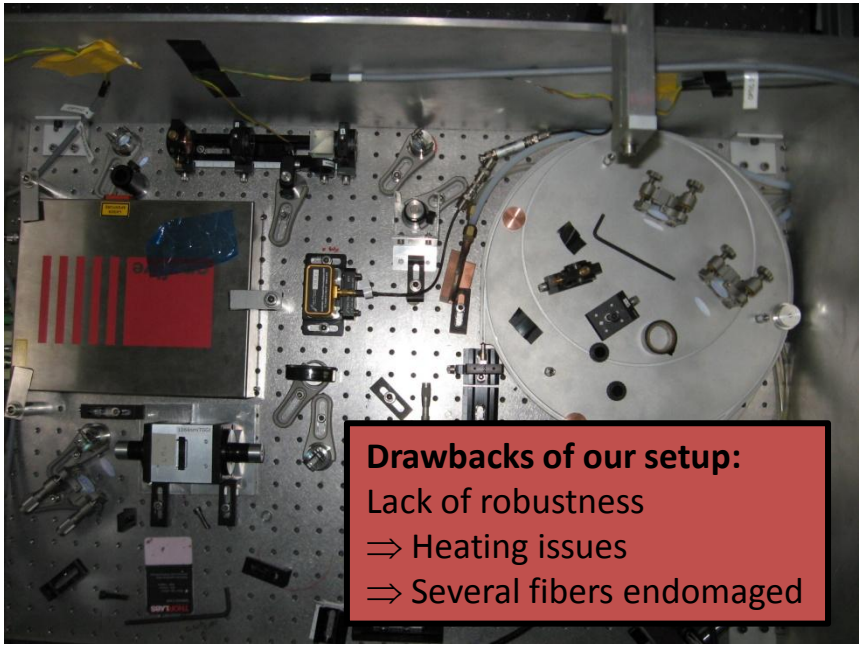
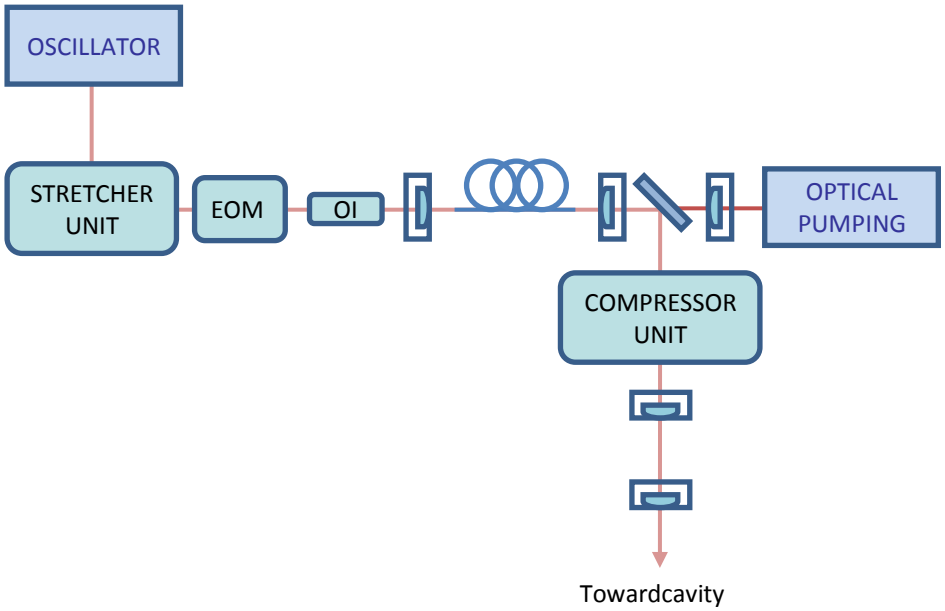
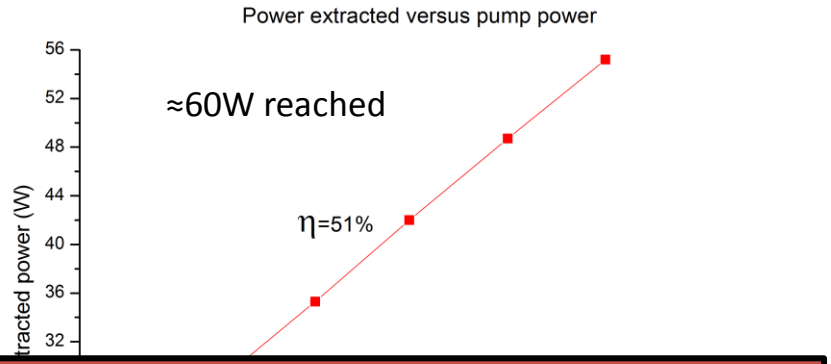


Drawbacks of our setup:
Lack of robustness
⇒ Heating issues
⇒ Several fibers endomaged





- Increasing of average power is possible (800W demonstrated with similar technique, *Limpert, OL35(2010)94)*
- R&D is needed on the heating and power handling

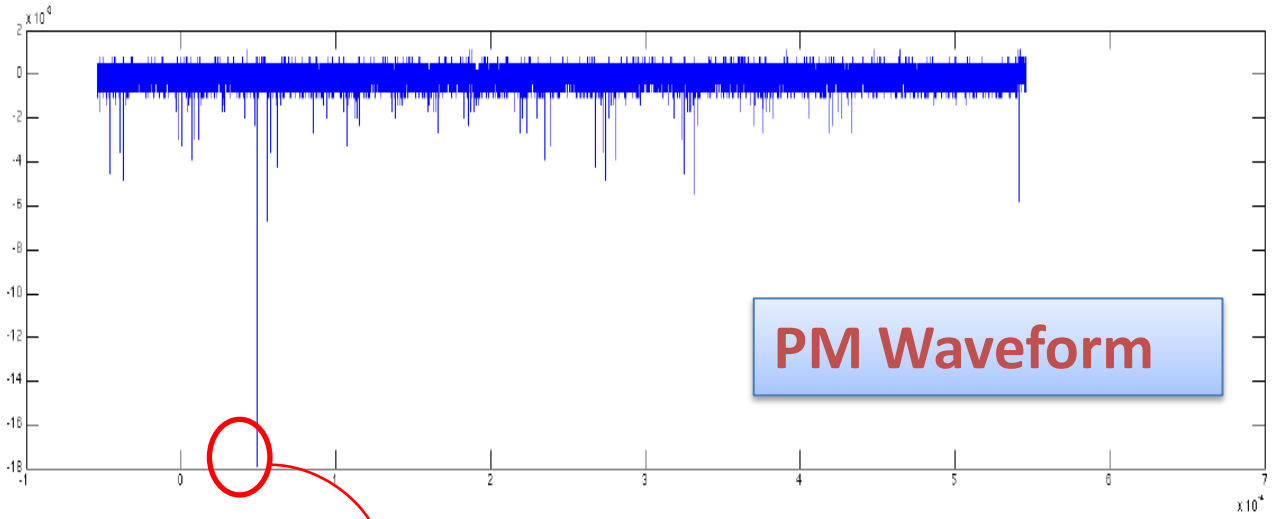
Results before the earthquake at the Accelerator Test Facility

One very short run before ATF breakdown (modulator on fire 3 week before the earth quake…)

✓Laser power ~10W

✓Cavity laser/coupling ~30% (best measured~60%)

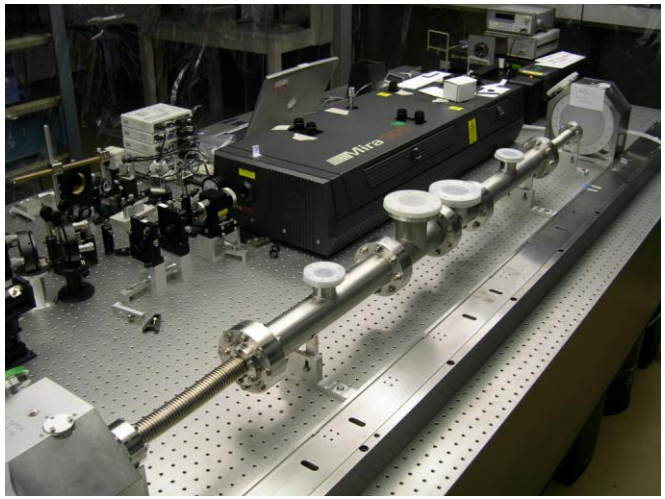
➔Power_cavity~3kW



It took few hours at KEK to 'find' the Compton signal

≈25/γ/bunch-Xsing (E_{max}=28MeV)

Work in progress



Ti:Sapph oscillator locked to a 30000 finesse two mirrors cavity at LAL

➔ Now gain ≈10000 aviable

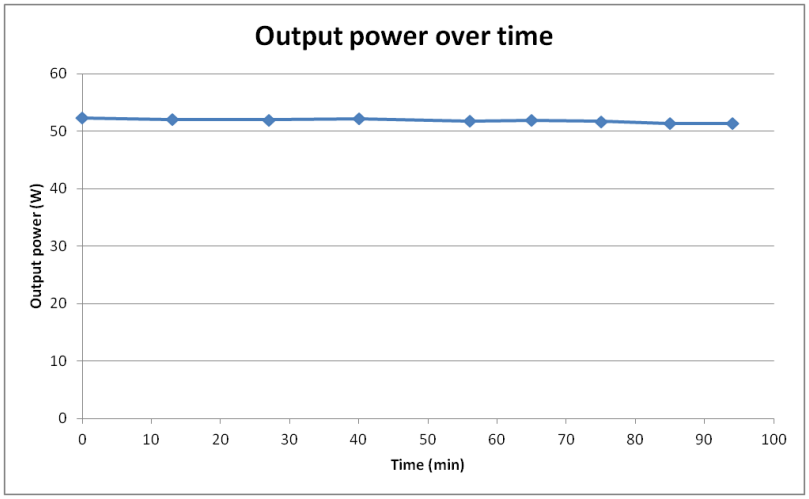
➔ Tests on our 4-mirrors cavity in progress

Improvement of amplifier design

➔ Now 50W of average power stable without eating issues

➔ Longer run next week

➔ 80W expected for next month



➔ New setup will be installed on ATF during the april/may shutdown

➔ Data acquisition expected for may

Goal : The ThomX machine

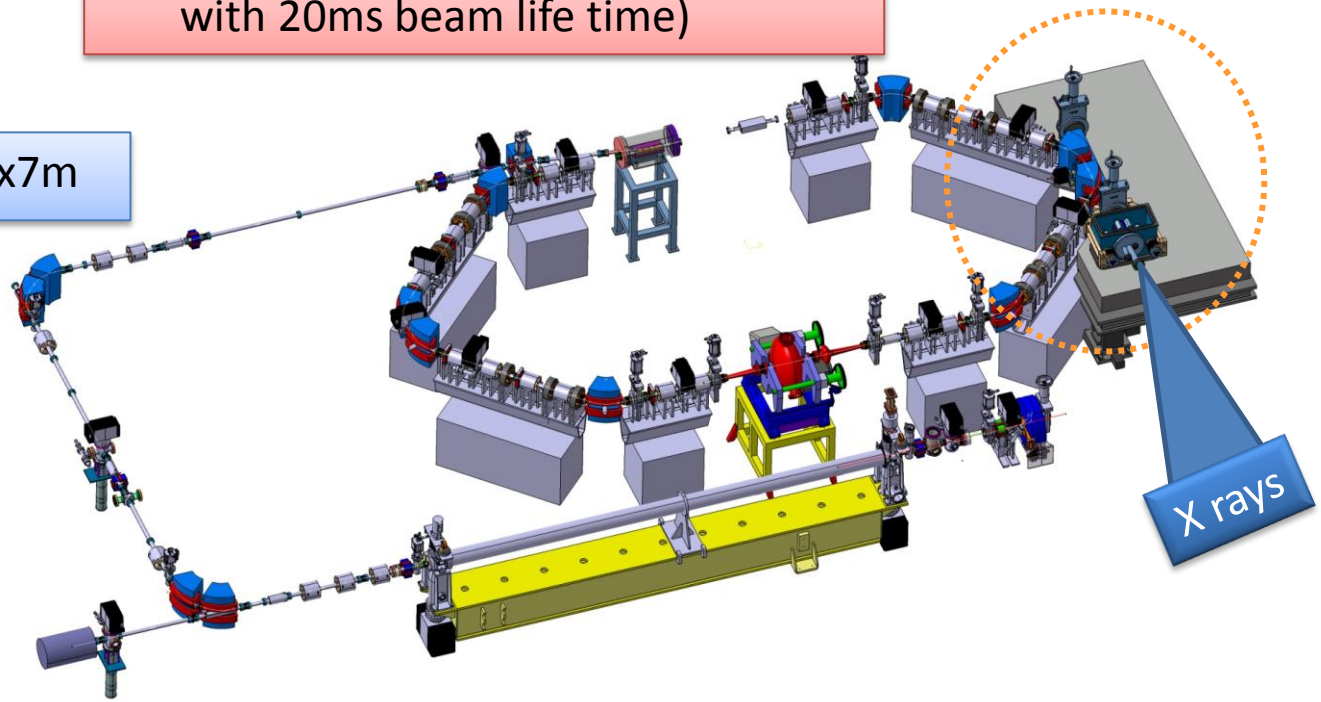
(≈10M€ funded EQUIPEX project)

~50MeV electrons
➔Compton Scattering perturbations
➔Intra beam Scattering …

➔ 'Transient machine' (we will start with 20ms beam life time)

Optical resonator

Size ~10mx7m



Summary

Monochromatic X-ray Compton scattering machines are interesting for a wide range of applications

R&D on the Fabry-Perot cavity and the laser system

➔ Higher cavity finesse

➔ Higher laser power

This R&D will leads to the ThomX project

Colaboration with Tsinghua University

➔ Phd student Yan You in co-direction will come to LAL next autumn

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Thank for your attention