Lasers For Life(L4L)

ATTOSECOND SPECTROSCOPY

(EARLY CANCER DETECTION WITH LASERS)

Abdallah Azzeer
Attosecond Science Laboratory Director

Nine strategic objectives to support KSU's mission

KSU's mission

To provide distinctive **education**, produce creative **research**, serve **society** and contribute in building the **knowledge economy** and community through learning, creative thinking **environment**, the optimal use of **technology** and effective international **partnership**

1. **Good everywhere; great in focus areas**
   Strengthen our comprehensive university with academic areas of research and teaching excellence
2. **Distinctive faculty**
   Attract and develop distinctive faculty
3. **Less is more**
   Increase student quality and reduce volume by raising entry requirements, increase the share of graduate students
4. **Stronger graduates**
   Enable KSU students to learn hard and soft skills throughout their academic life
5. **Building bridges**
   Build bridges internally within KSU and externally with local and inter-national groups
6. **Supportive learning environment**
   Create an engaging environment at KSU for faculty, students, and staff
7. **Sustainable future**
   Build KSU's endowment and diversify sources of funding
8. **Flexibility and accountability**
   Create a performance contract with the government
9. **Organizing for purpose**
   Establish an organization and governance model that support KSU's mission

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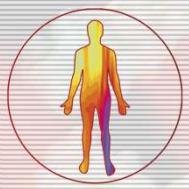
Source: KSU Strategic Planning Committee; team analysis

Outline:

- History
- Aim
- Background
- Concept



Lasers4Life

History:

(First Phase)

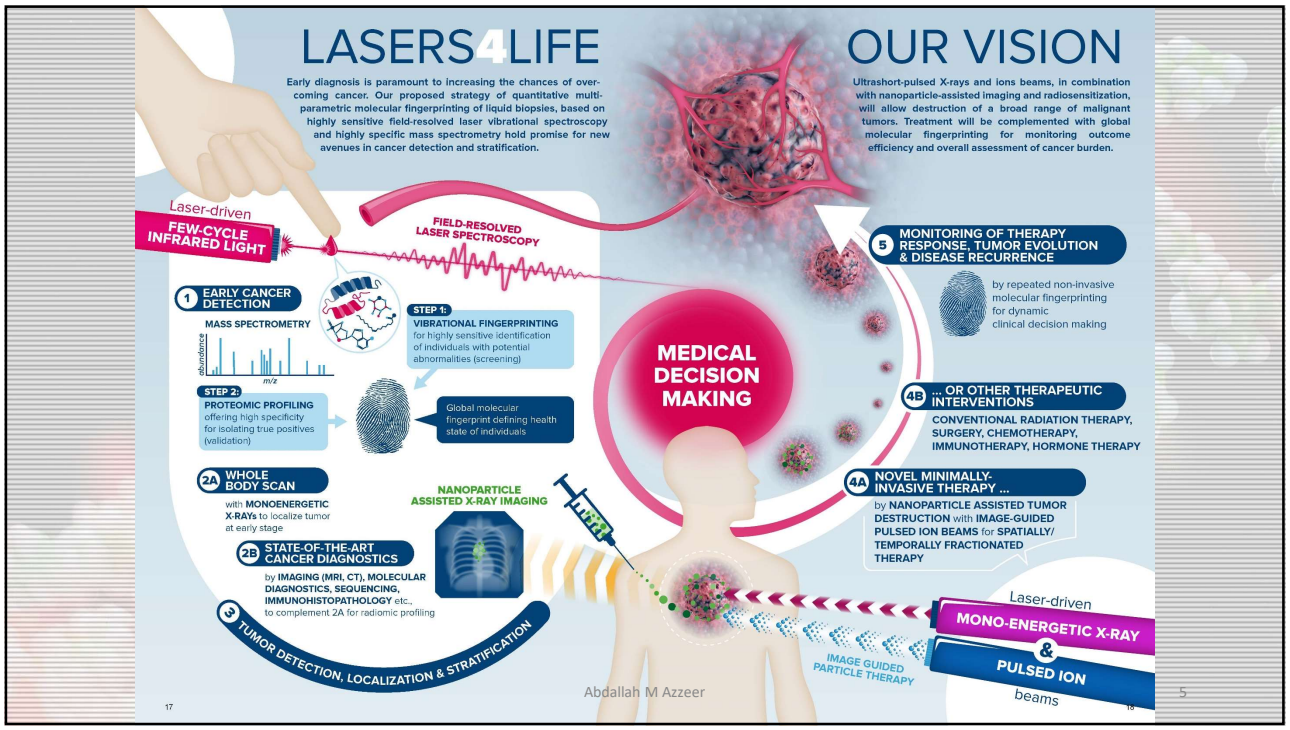
Signing of the first research cooperation between MPQ and KSU (2008 - 2012)

(Second Phase)

Installation of the Attosecond Laser Source Lab at KSU (2012 - 2015)

(Third Phase)

Signing of the MoU between LMU and KSU and opening the new Lab (2013 - 2015)



FROM CAUSALITY TO SINGULARITY

- Our approach is fundamentally different from the present **concept of Causality,** developed by the Prof. Claude Bernard in his "Treaty of Experimental Medicine" (1865), who links an observable phenomenon to its causes and consequences (**limited number of variables**..) with a probabilistic/classical statistical approach, widely and exclusively used for the last 150 years

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FROM CAUSALITY TO SINGULARITY

- Our approach introduces the concept of **Singularity** (from singula in Latin meaning individual…), allowing to define with liquid biopsies (simple blood tests) the **unique individual molecular profiles of a person at a given time with Thousands to Million to Billion variables**, encompassing DNA, RNA, proteins, effectors of the immune system, catabolites of normal and cancer cells, physiologic effectors of homeostasy…).

FROM CAUSALITY TO SINGULARITY

- The **'molecular profiles at n variables' of a given patient/subject at a given time is unique.** Through the artificial intelligence integration of all variables obtained by the Quantum Optics technology (Molecular truth…), we have the opportunity to obtain an **individual response to a given medical question with a 99+% probability**, hence the **concept of Singularity…** To understand the approach, an analogy can be made with facial recognition processes, which, with 80-170 variables (distance between the eyes, size of the mouth…and so on), allow to identify each of us with a 99.99% probability: **singularity**…If only a limited number of variables were used, only a limited probability will be shown (20-30 at best 40%...): **causality**…needing advanced probabilistic statistical analysis…

FROM CAUSALITY TO SINGULARITY

- **The batteries of algorithmic tests** are potentially allowing to address biologic and medical issues in a binary approach: for example presence or not of a given cancer at the present time for a given person, efficacy of a given medication at a given time for a given patient… a multitude of question can be potentially addressed with the proper algorithms…

FROM CAUSALITY TO SINGULARITY

Two main medical applications are being targeted by our group at the present time

- **Detection of early cancer** using individual **"molecular/atomic profiles at n variables"** to differentiate healthy controls and individuals with early cancer: the goal is to replace existing cumbersome and expensive screening programs (breast, colon cancers…) and introduce early detection in all various types of cancers with no present screening strategies
- **Individual prediction of efficacy or resistance to cancer medication** at a given time, allowing to predict upfront efficacy/resistance to cancer medications for given patients. Today, we treat large groups of cancer patients for a benefit restricted to a fraction of them (15 to 20% in average…). Considering the large number of biologics agents either available or coming, identifying upfront the right patients for the right medication with a potential efficacy of 98% to 99% could have, as well, a huge impact on medical and socio-economic aspects…

Potential applications of the concept of Singularity

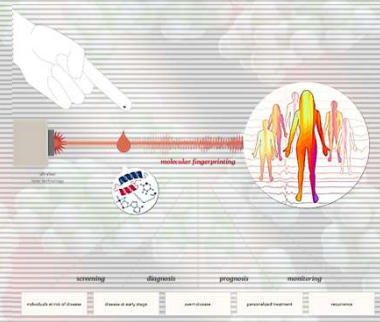
- The 2 directions of research shown above, early cancer detection and prediction of cancer medication efficacy and resistance could lead to significant advances in cancer medicine and could represent the first step towards the medicine of the XXI century: **Numeric Quantum Medicine towards the real individualized medicine**.

The Aim:

The aim of Lasers4Life (L4L) is to explore the utility of cutting edge ultrafast laser techniques, combined with state-of-the-art mass spectrometry, for developing novel cost-effective approaches to sensitive and robust cancer probing, localization, and tumor destruction.

The Molecular Fingerprint

Ultrashort pulses of laser light can be used to analyse the molecular composition of blood samples (serum or plasma) and can therefore reveal changes in states of health. The laser pulses excite the molecules in the sample, causing them to vibrate and emit broadband infrared radiation, which contains structural information about the molecules present in the sample. By comparing this signal with the emission from a reference sample, one can obtain a spectrum (molecular fingerprint) that reveals the differences in composition between the two samples…



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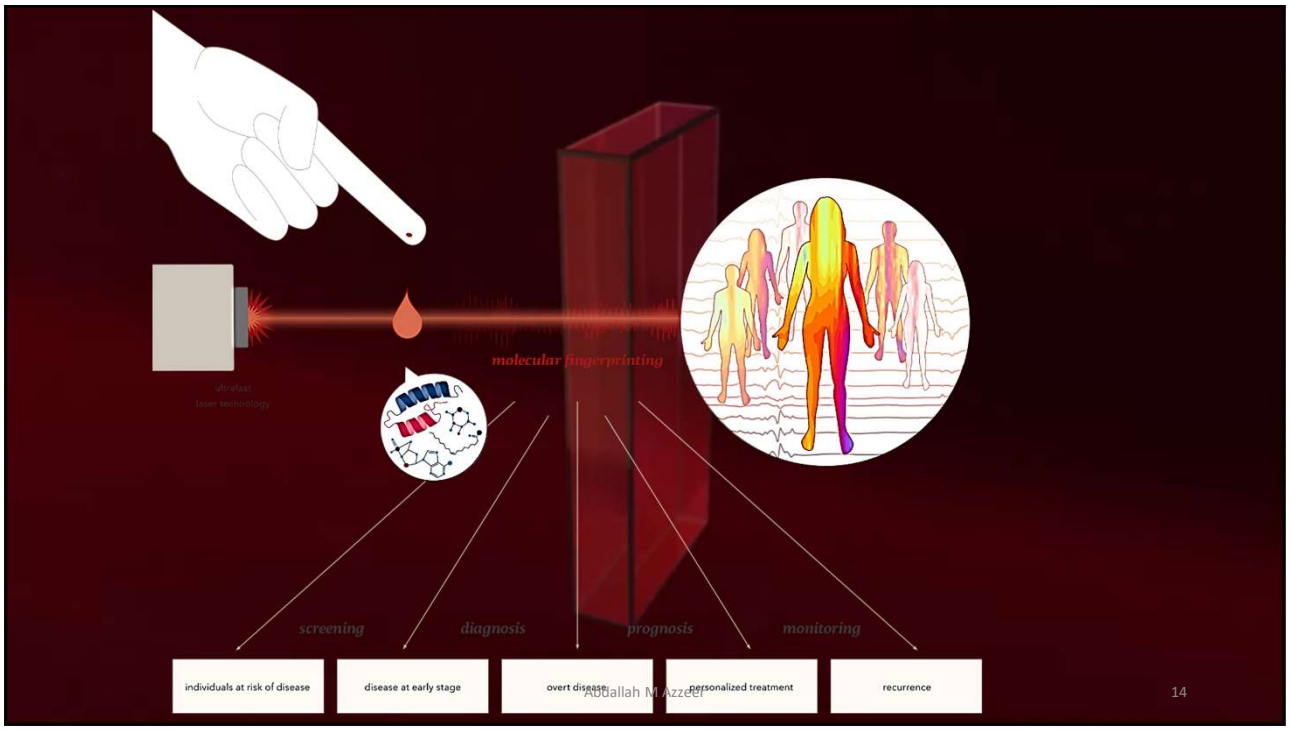

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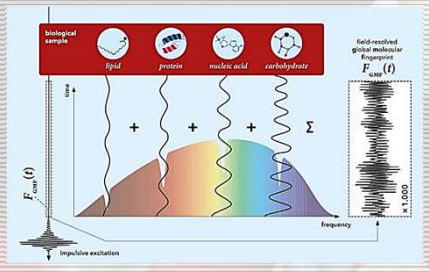
The Concept:



Electric Field Detection

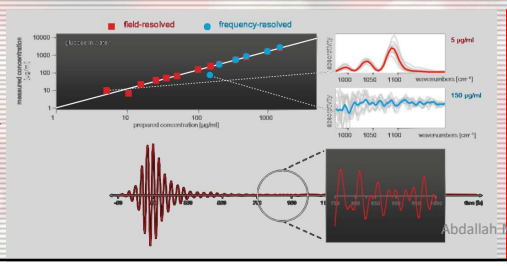
$E_{out}(t)$

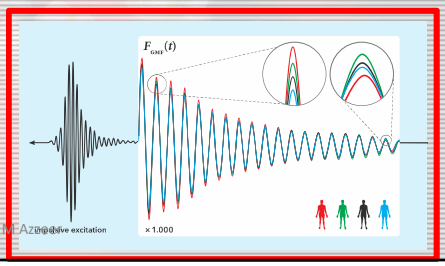
$E_{GMF}(t) = E_{out}(t) - E_{in}(t) \propto P_{sample}(t)$

× 1,000

$E_{in}(t)$

Infrared Laser Source

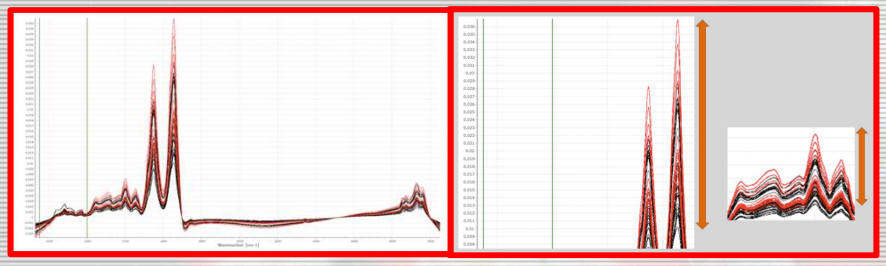




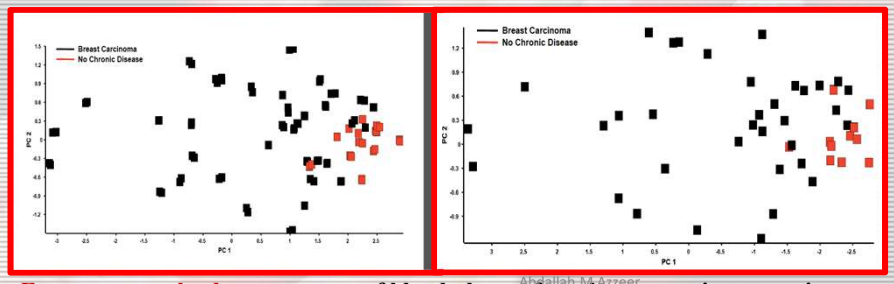
preliminary study: suggesting existance of fingerprints specific to individuals

The Concept:

Riyadh plasma samples - overview:

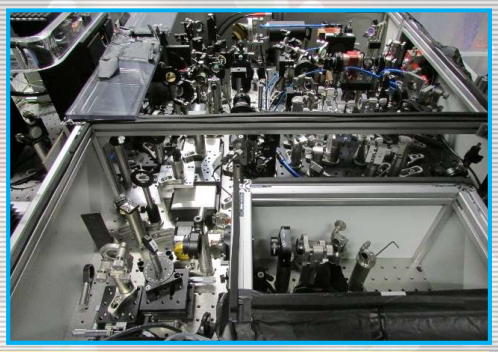


3-5x difference in molecular concentrations (proteins & carbohydrates)



2 independent rounds of measurements principle component analysis

Frequency resolved spectroscopy of blood plasma from breast carcinoma patients



- View of the Infrasampler prototype at the LMU. Near-infrared pulses generated by a femtosecond oscillator drive the nonlinear optical process of difference-frequency mixing, resulting in broadband, ultrashort, phase-stable mid-infrared pulses. These are propagated through a cell containing automatically delivered samples of biofluids. The transmitted waveforms are sampled with copies of the initial near-infrared ultrashort pulses. Taking advantage of the full coherence of the infrared waveforms, this spectroscopy scheme reaches unprecedented sensitivity for measurements of biological fluids.

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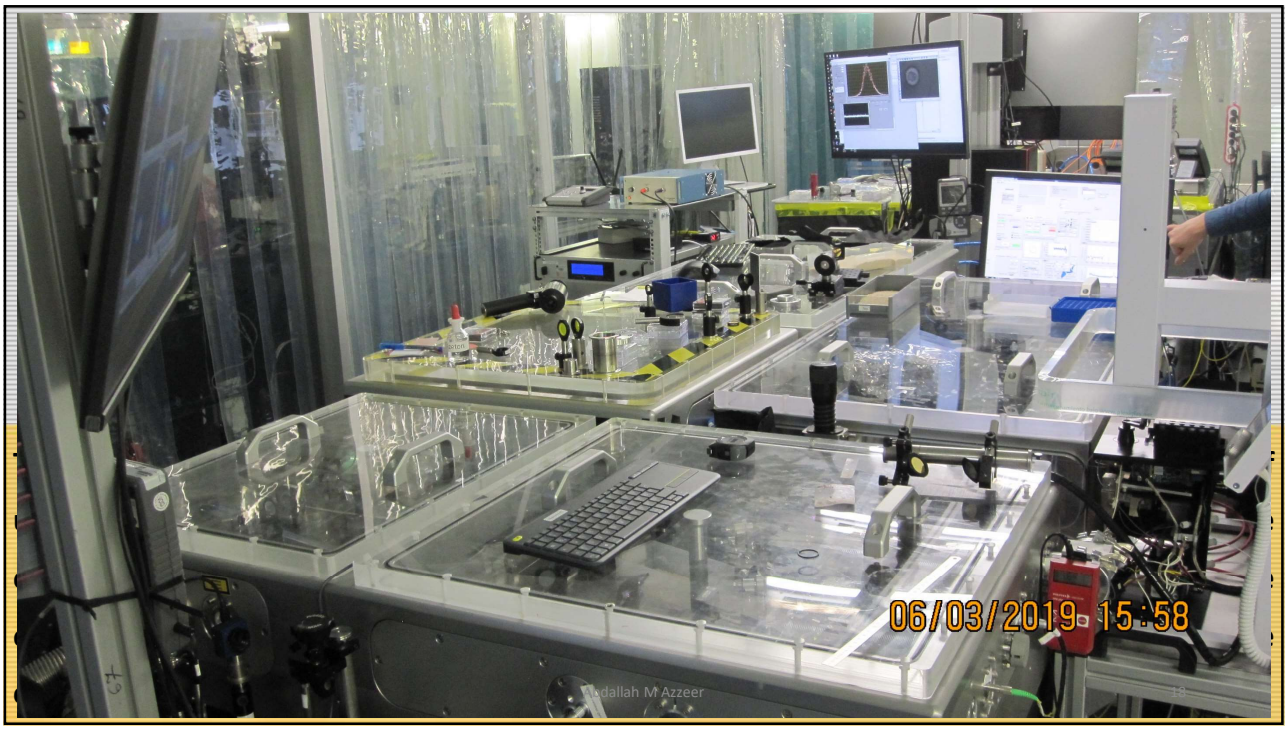


ECDL-KSU Team	ECDL-LMU_MPQ Team
Abdallah Azzeer	Ferenc Krausz
Jean-Marc Nabholtz	Mihaela Zigman
Khalid Al Saleh	Ioachim Pupeza
Meshaal Alharbi	Alexander Apolonskiy
Ayman Alismail	Matthias Kling
Hisham Alhadlaq	Marinus Huber
Haitham Alrabiah	Michael Trubetskov
Aws Alshamsan	Wolfgang
Ghada Badr	Schweinberger
	Syed A. Hussain
Nasser Al-Daghri	Christina Hofer
Omar Al-Attas	Kilian Fritsch
Majed Alokail	Markus Pötzlberger
	Lenard Vamos
	Nicholas Karpowicz
	Vladimir Pervak
	Oleg Pronin

Attosecond Facility at KSU

http://attoworld.sa/

- According to King Saud University (KSU) strategic plan 2030, one of their pillars is to build bridges with international groups. King Saud University, established in 2008 a Satellite Lab, through the International Twinning Program, in conjunction with the Max Planck Institute for Quantum Optics (MPQ) and the Ludwig-Maximilians University (LMU) , so as to activate the joint research collaboration in the field of very advanced laser research, and take advantage of the infrastructure and global expertise.
- In 2015, the partners established a world-class Attosecond Science Laboratory (ASL) at KSU where outstanding senior and young scientists will work together on the development and application of novel radiation sources for coherent ultrashort intense light pulses. The ASL is considered to be the 6 branch of MPQ outside Germany.
- The MPQ-KSU-LMU Collaboration facilitates the partners to establish forefront research and education in one of the key technologies of the 21st century, Photonics. Photonics, the science and technology of laser light and its widespread applications, belongs to the fastest growing and developing technologies of the 21st century.
- The research areas for this collaboration include medical diagnosis, next-generation intense laser sources, lightwave nanoelectronics, and photonic reagents for the control of chemical processes.

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

جامعة الملك سعود King Saud University

ASL Opening Ceremony 16/2/2015

Excellency Prof. Dr. Badran Al-Omar, The University's Rector,

Prof. Dr. Ahmed Alamri Vice Rector for Graduate Studies and Scientific Research

- Prof. Dr. Theodor W. Hänsch
  2005 Nobel Prize in Physics
- Prof. Dr. Paul Bruce Corkum
  2013 King Faisal Prize for Physics,
  Joint Laboratory for Attosecond Science
- Prof. Dr. Ferenc Krausz
  2013 King Faisal Prize for Physics,
  Director of The Max Planck Institute of Quantum Optics
- Prof. Dr. Gérard Mourou
  Director of IZEST (International Zettawatt Exawatt Science and Technology)
- German Ambassador to the Kingdom of Saudi Arabia Mr. Boris Ruge

ASL Opening Ceremony 16/2/2015






nature

Saudi Arabia opens top-notch laser lab

Facility will study biomedical uses at attosecond resolution.

Alison Abbott

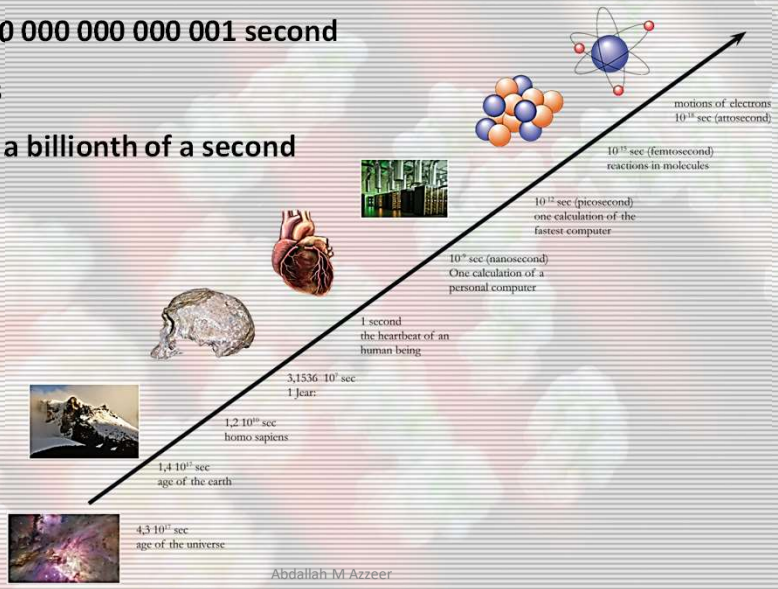
17 February 2015

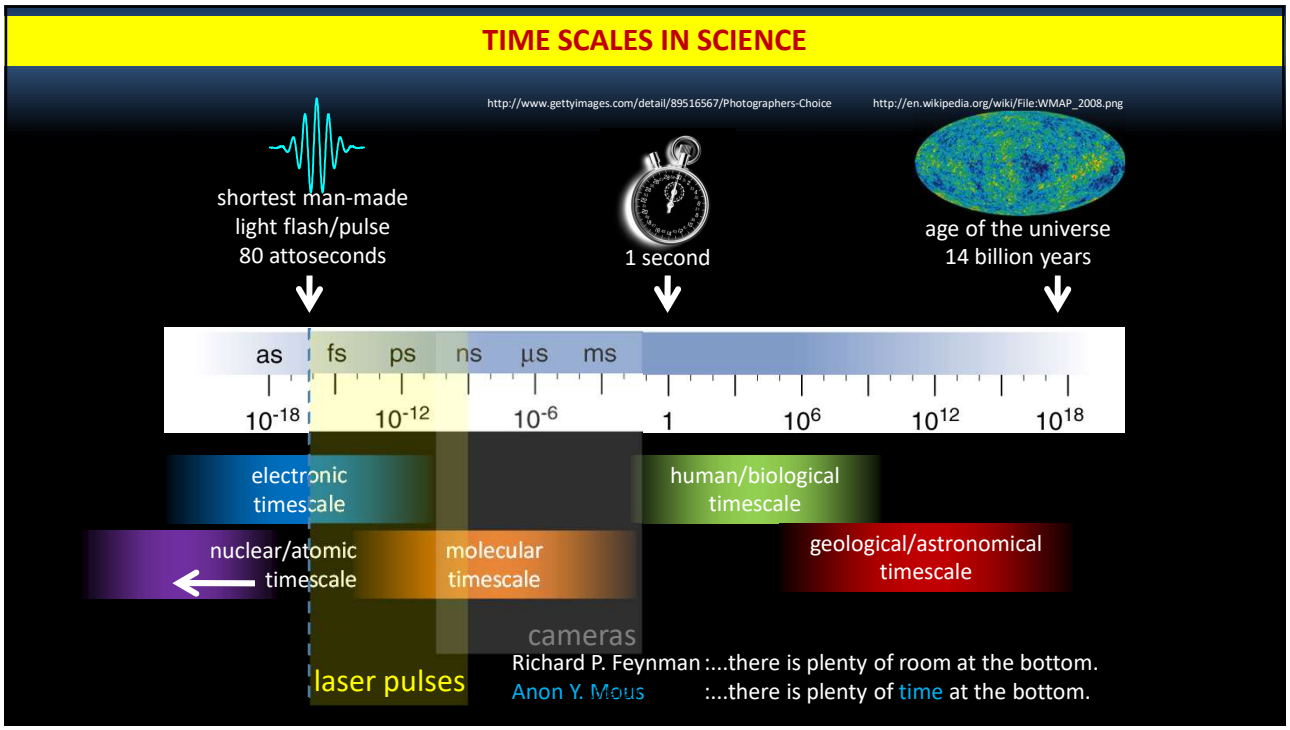

THE DIMENSION OF AN ATTOSECOND

1 as = 0,000 000 000 000 000 000 001 second

= 10^{-18} seconds

= a billionth of a billionth of a second





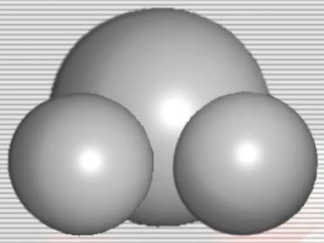
One way to visualize an attosecond

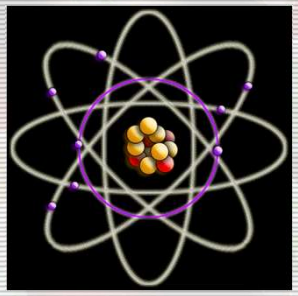
- **If you travelled at the speed of light:**
- **You would circumnavigate the earth 10 times in a second.**

- **You would circumnavigate an atom only one in 1 attosecond!**

- **The attosecond idea; pull an electron from an atom, then use the laser light to drive it back;**

Molecular vibrations can be very fast!





Characteristic time scale:

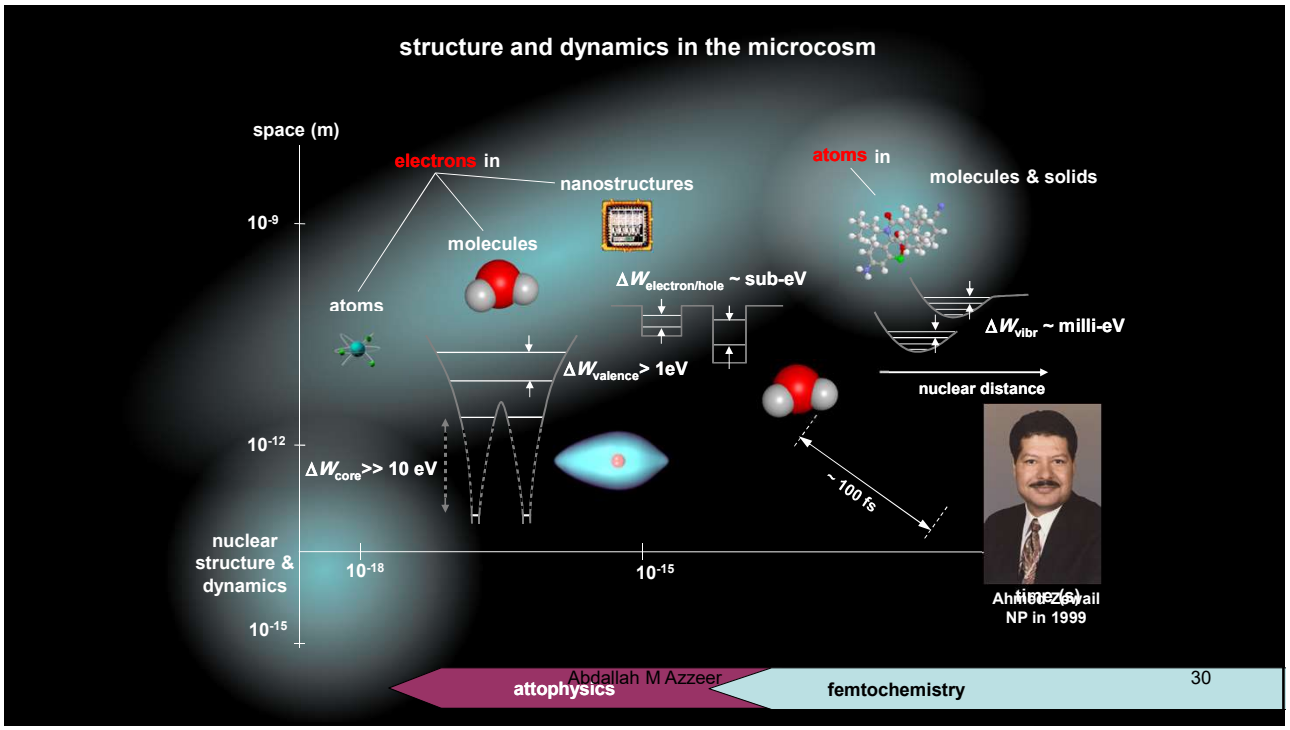
Vibrational oscillation period:

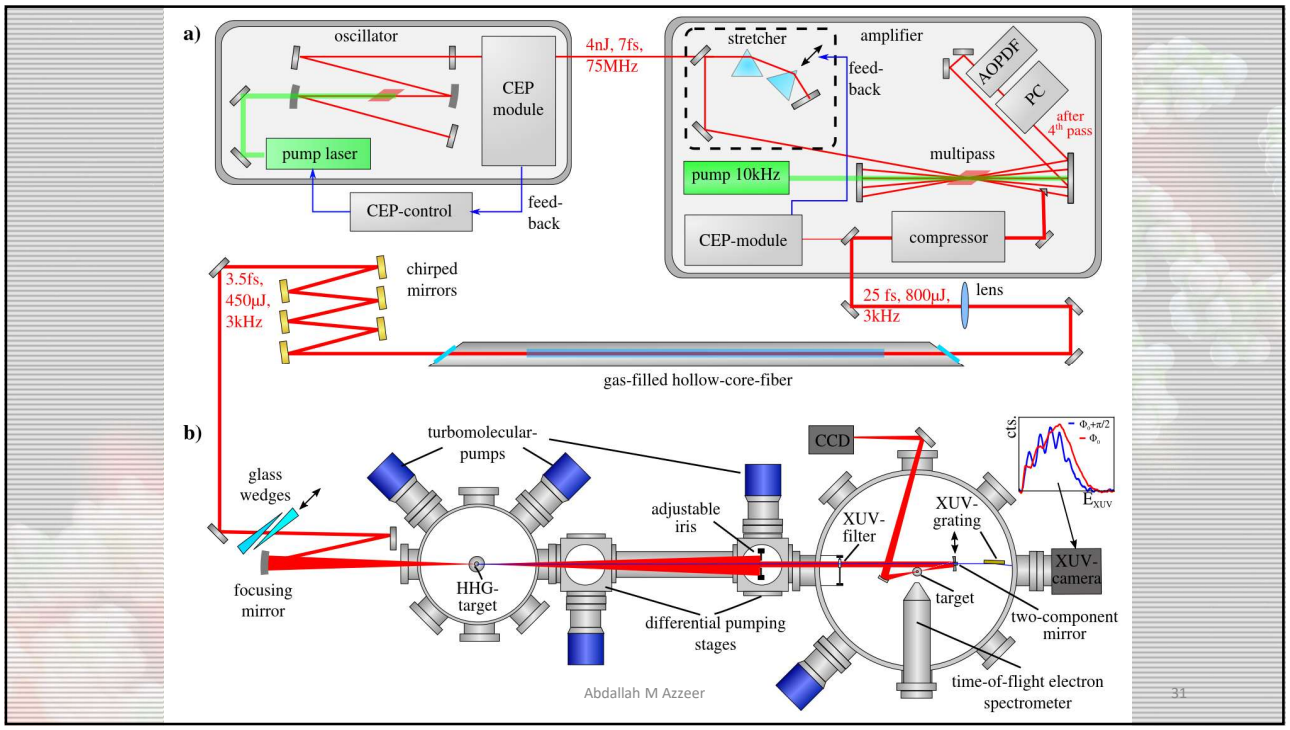
~ 7 fs (H_2)

Characteristic time scale

Bohr-orbit time in hydrogen:

152 attoseconds




a)
oscillator
CEP module
pump laser
CEP-control
feed-back
4nJ, 7fs, 75MHz
stretcher
amplifier
feed-back
AOPDF
PC
after 4th pass
multipass
pump 10kHz
CEP-module
compressor
25 fs, 800µJ, 3kHz
lens
3.5fs, 450µJ, 3kHz
chirped mirrors
gas-filled hollow-core-fiber
b)
turbomolecular-pumps
CCD
cts
glass wedges
adjustable iris
XUV-filter
XUV-grating
XUV-camera
focusing mirror
HHG-target
target
two-component mirror
differential pumping stages
time-of-flight electron spectrometer
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strategic alliances
In order to promote proliferation of our discipline and dissemination of knowledge in general, we have established strategic partnerships with several groups in countries with most dynamically expanding economies and greatest ambitions in creating and advancing knowledge-based societies.
LAP
PEKING
TOKYO
SHANGHAI
POHANG
RIYADH
BRISBANE
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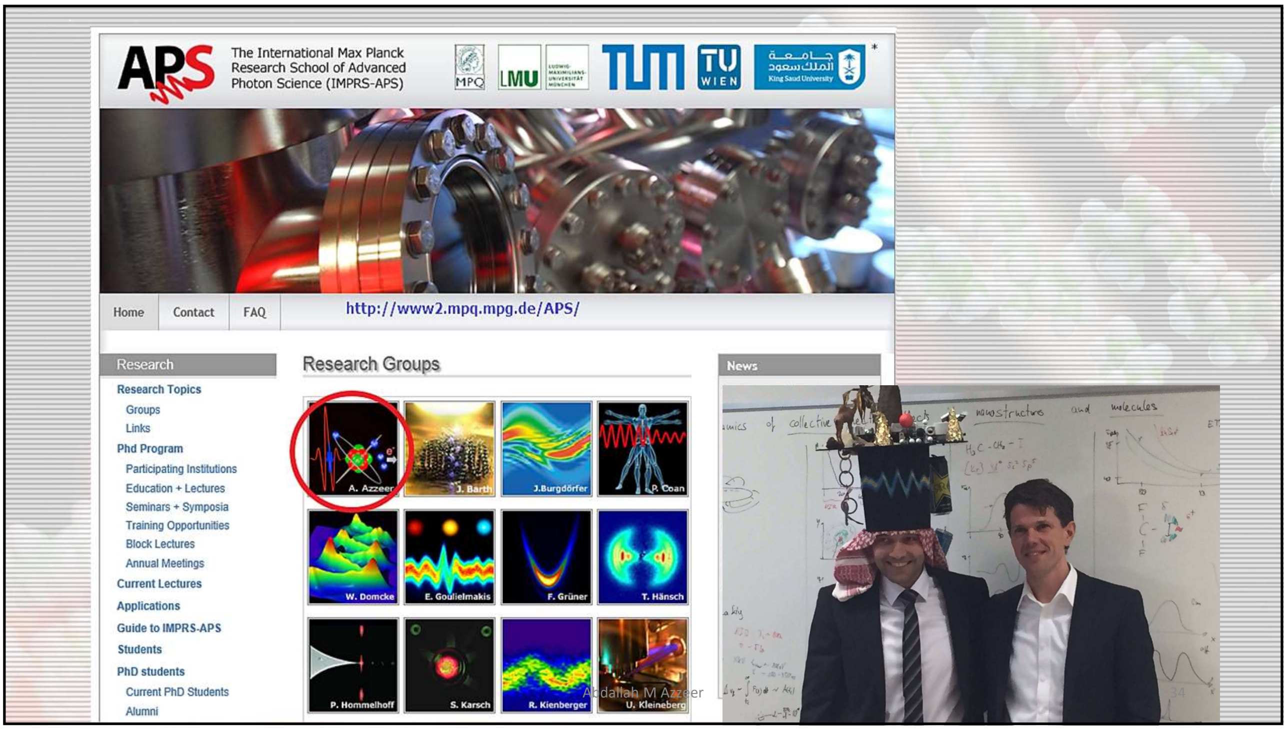
The International Max Planck Research School of Advanced Photon Science (IMPRS-APS)
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P. Hommelhoff
S. Karsch
R. Kienberger
U. Kleineberg
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م	المشاركين	العدد
1	اعضاء المجموعة من داخل الجامعة معيدين	قسم الفيزياء (4) - كلية الطب (4) قسم الفيزياء (2)
	أعضاء من خارج الجامعة	مدينة الملك عبدالعزيز للعلوم والتقنية (2) جامعة الملك عبدالله للعلوم والتقنية (2)
2	أوراق علمية	27
3	مؤتمرات	18
4	ورش عمل وندوات	12
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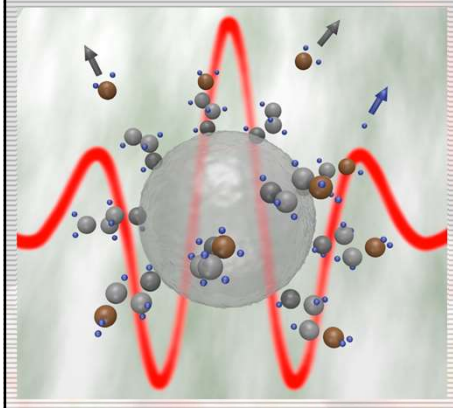
6	تدريب طلاب وطالبات سعوديين في مختبرات معهد ماكس بلانك للبصريات الكمية وجامعة لودفيغ ماكسميليان بالمانيا	22
7	عدد طلاب الدكتوراة ومابعد الدكتوراة عملوا في المختبر خلال الفترة الماضية (من الجانب الالماني)	7
8	طلاب دراسات عليا	3

THAK YOU



We are not going to take a real steps forward if we are not willing to engage with the unknown