

TERACOMB

an FP7 project



Quantum cascade laser based TERAhertz frequency COMB

(FET open project and a way into it ...)

www.teracomb.eu

Juraj Darmo

Technische Universität Wien, Institut für Fotonik

Talk outline

1. TERACOMB facts' sheets

- Project basic information
- Project objectives
- Project consortium and the role of partners

- Technicalities
 - What is terahertz wave?
 - What is quantum cascade laser?
 - What is frequency comb?

2. Road to TERACOMB project

Project timeline

Notes on the project negotiation

Notes on the project running

TERACOMB key facts

Item	Details	EC-GA Article No.
Title of Project	Quantum cascade laser based terahertz frequency combs	No. 2 + Page 2
Acronym	TERACOMB	No. 2 + Page 2
Grant Number	296500	Page 2
Call	FP7-ICT-2011-C	
Type of Grant	Collaborative Project	Page 2
Max. EC Contribution	€2,192,598.00	No. 5.1
Project start date	01.06.2012	No.3
Project duration	36 months	No.3

TERACOMB consortium

Role	Entity	Country
Coordinator / Partner	Technische Universität Wien Institut für Fotonik	AT
Partner	University Paris Diderot – Paris 7	F
Partner	Eidgenoessische Technische Hochschule Zürich	CH
Partner	Institut d'Optique Théorique et Appliquée IOTA - Supoptique	F
Partner	University of Cambridge Cavendish Laboratory	UK
Partner / SME	Menlo Systems GmbH	D

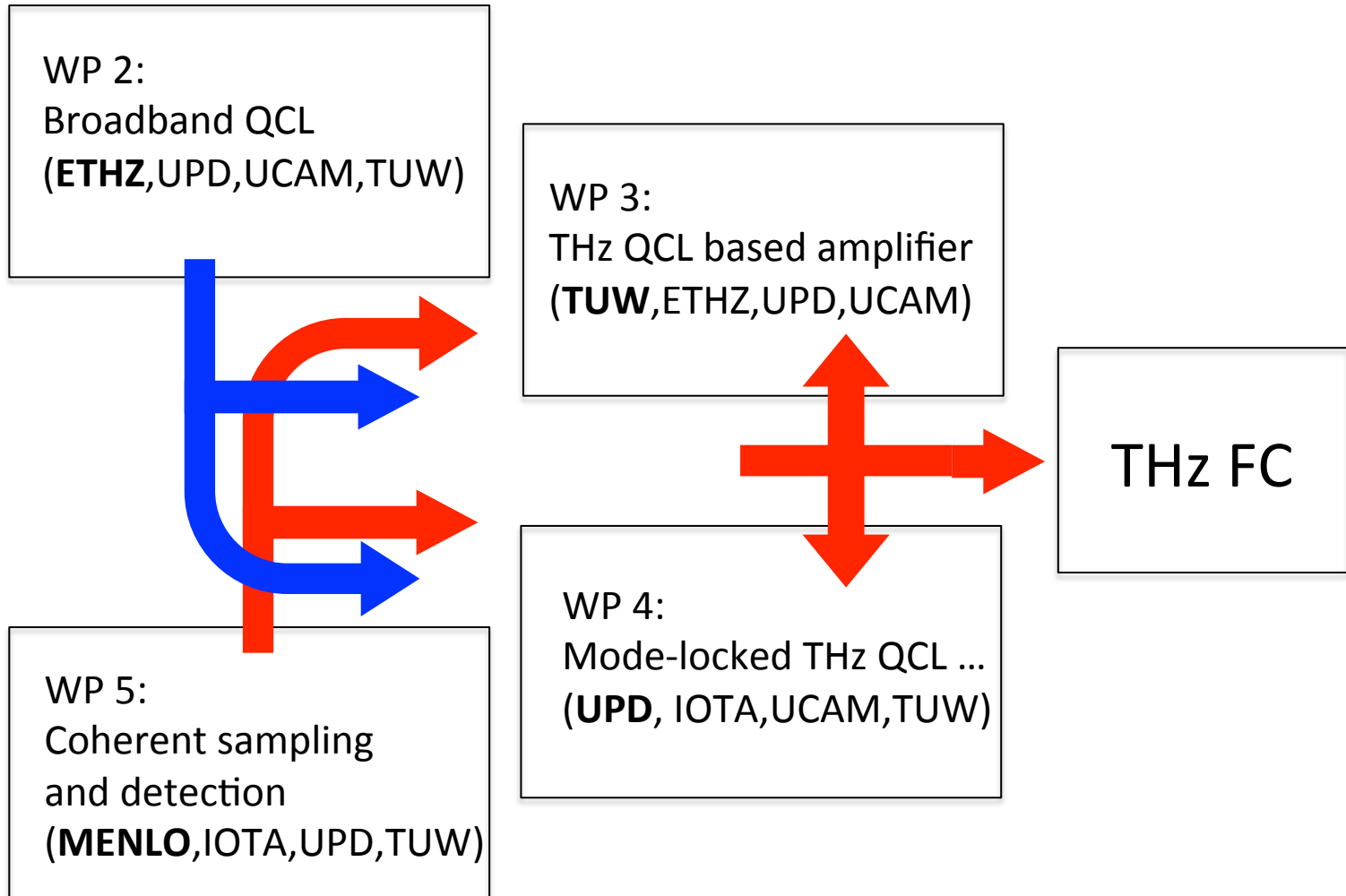
TERACOMB objectives

1. Broadband (bandwidth of 1 THz) cw THz QCL with regular comb teeth
2. 1-THz broad frequency comb based on a mode-locked QCL generating sub-ps pulses
3. 1-THz broad QCL-based amplifier for boosting the power of THz frequency comb
4. Development of a technique to increase the time resolution of the coherent sampling of QCL

TERACOMB Workpackages

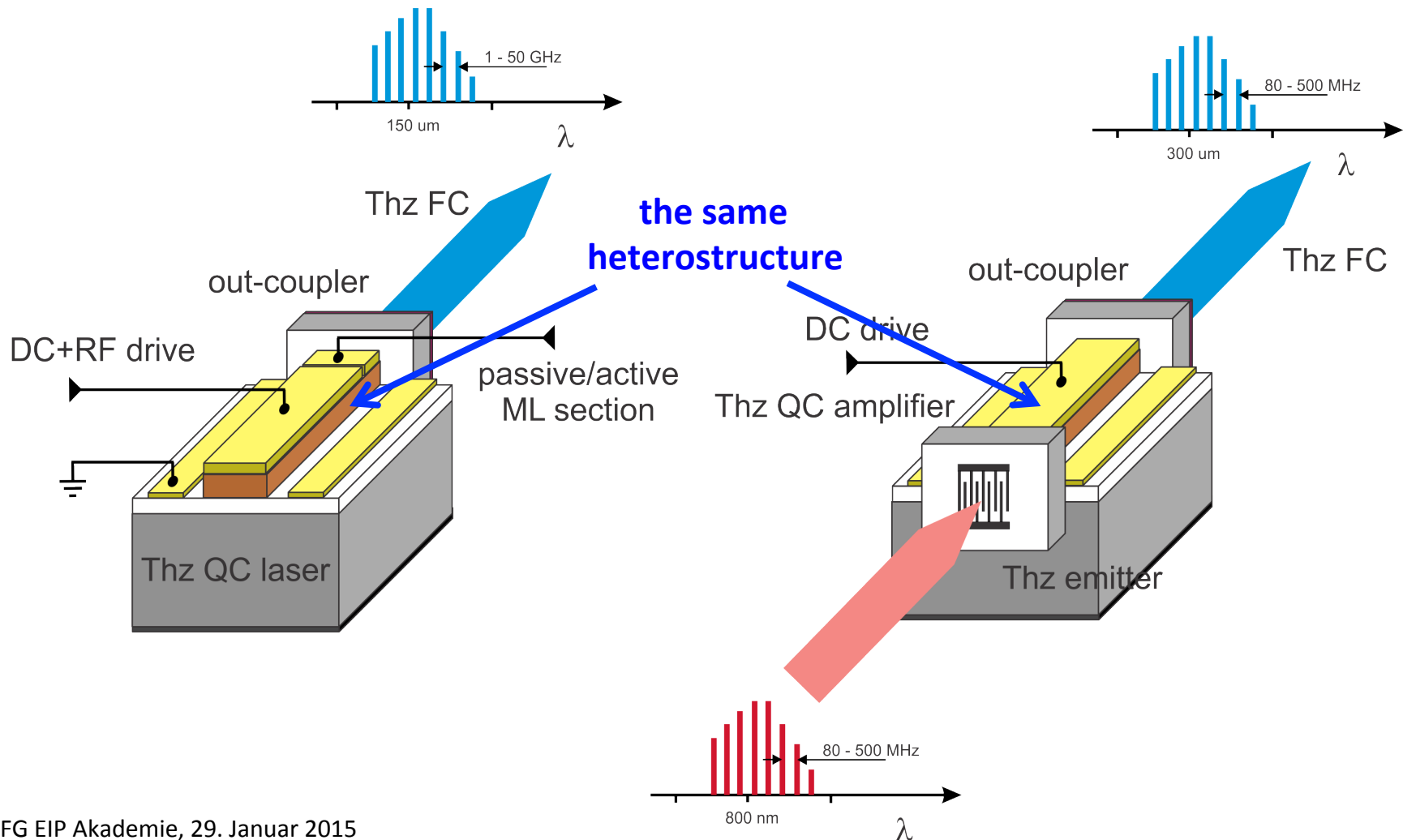
WP No.	Title	Activity Type	Leader
1	Project Management and dissemination	MGT	TUW
2	Broadband QCL	RTD	ETHZ
3	1-THz broad FC based on QCL amplifier	RTD	TUW
4	1-THz broad FC based on mode-locked QCL	RTD	UPD
5	High time resolution coherent sampling and high SNR coherent detection	RTD	MENLO

TERACOMB objectives



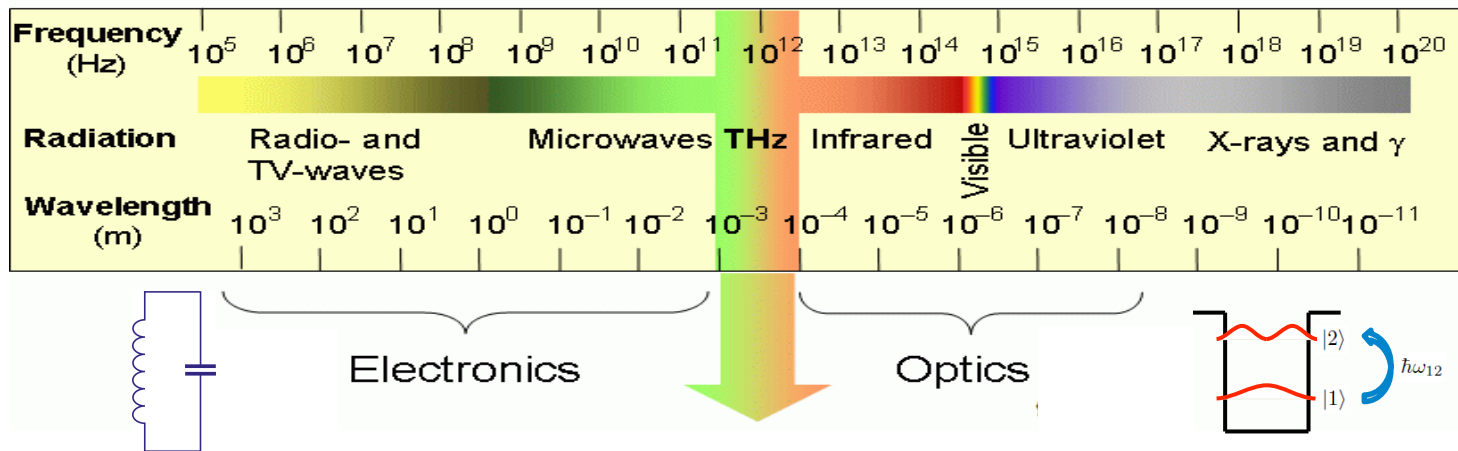
TERACOMB objectives

- generation of terahertz frequency combs by means of quantum cascade laser heterostructure



What are (good for) Terahertz (waves) ?

terahertz frequency range - electromagnetic spectrum between RF and optics (0.3 – 10 THz) - formerly called *far-infrared* and dominated by astronomers

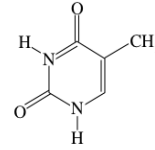
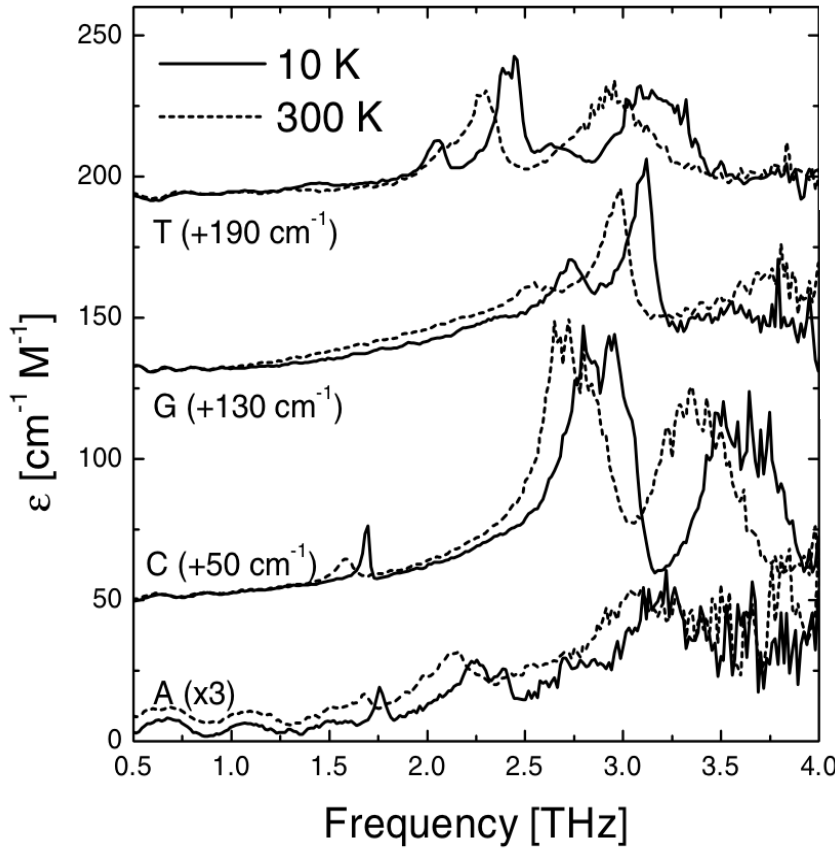


- + material response:** - molecular and inter-molecular vibrations and rotations
 - provides chemical contrast for sensing/finger printing
- + safe:** - non-ionizing photons (very low photon energy \sim meV)
- +/- short range:** - high absorption in air (due to water vapor \sim 100 dB per 100 m)

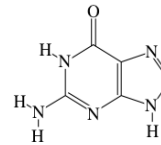
photonics – robust generation of the waveform; wave guiding; sensitive detection of the light for the information processing

What are (good for) Terahertz (waves) ?

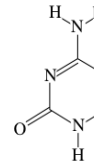
... chemical sensing



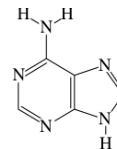
thymine (T)



guanine (G)



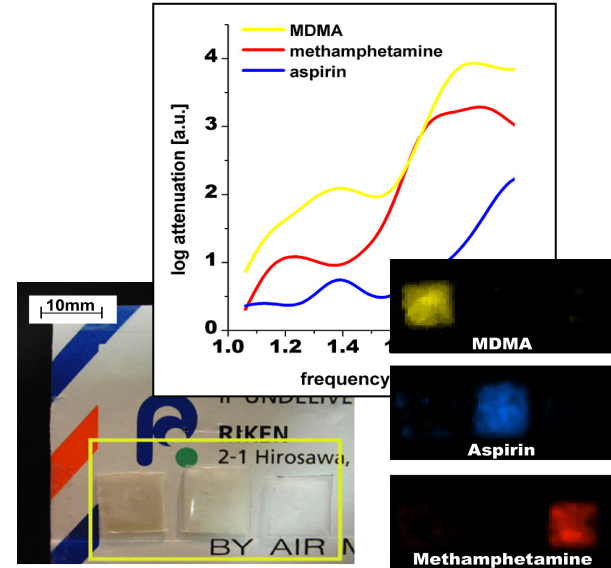
cytosine (C)



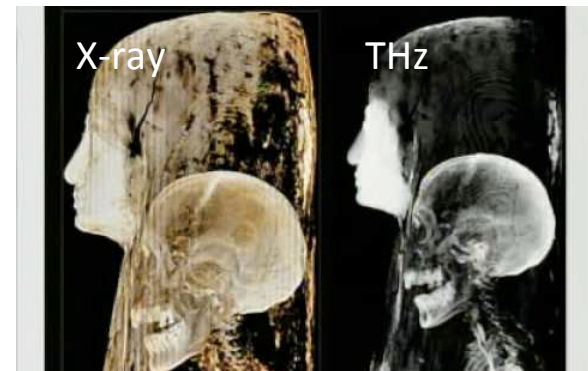
adenine (A)

M.Fischer et al., Phys.Med.Biol. 47, 3807 (2002)

... security screening



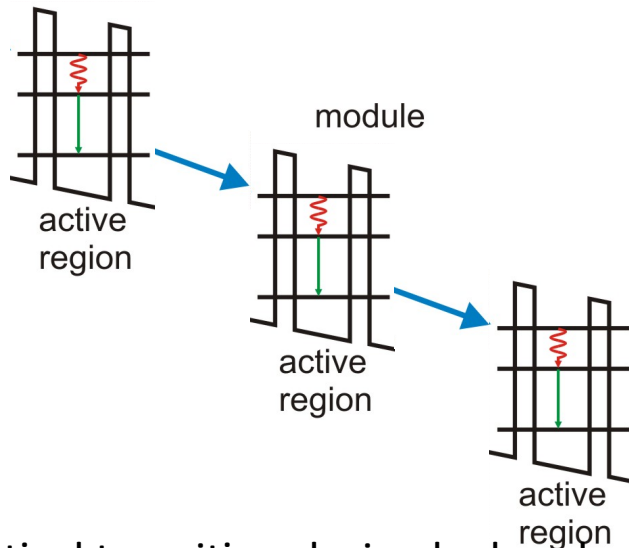
... non-destructive testing
(cultural heritage screening)



©RIKEN, Sendai

What is (good for) quantum cascade laser ?

Quantum Cascade Laser



- optical transition design by band structure engineering in heterostructure
- different material systems available
- accessible wavelengths 4 – 300 μm
- electron recycling (high efficiency)
- output power proportional to number of cascades

State-of-the-art

frequency range:

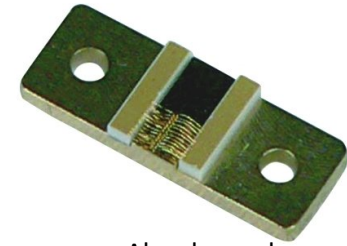
1.2 – 4.9 THz

output power:

>100 mW

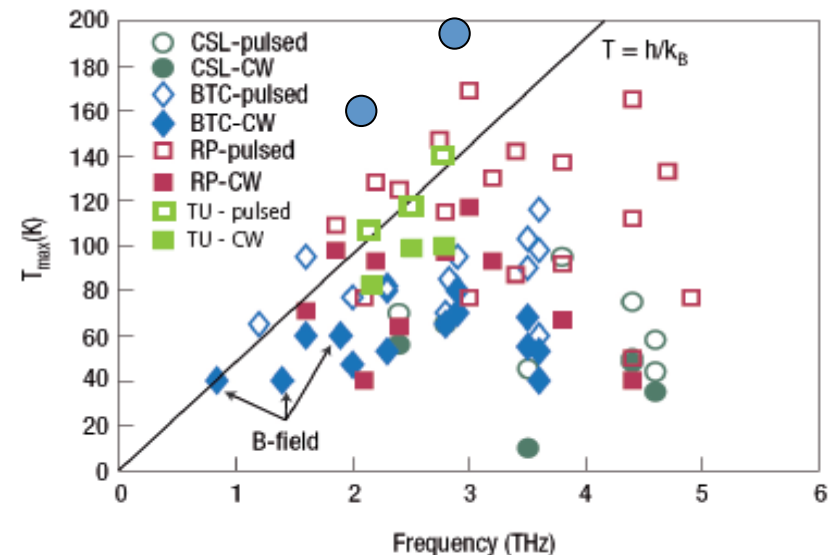
operation temperature:

< 200 K, typically 80 K



Alpeslaser.ch

T_{max} versus lasing frequency

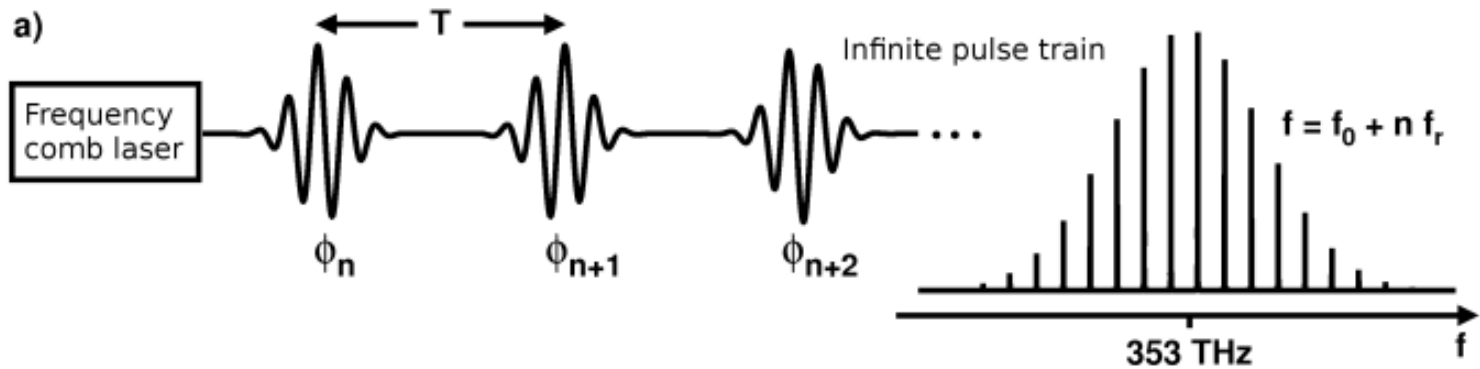


J.Faist et al., Science 264, 391 (1994) – first MIR QCL
R.Kohler et al., Nature 417, 156 (2002) – first THz QCL

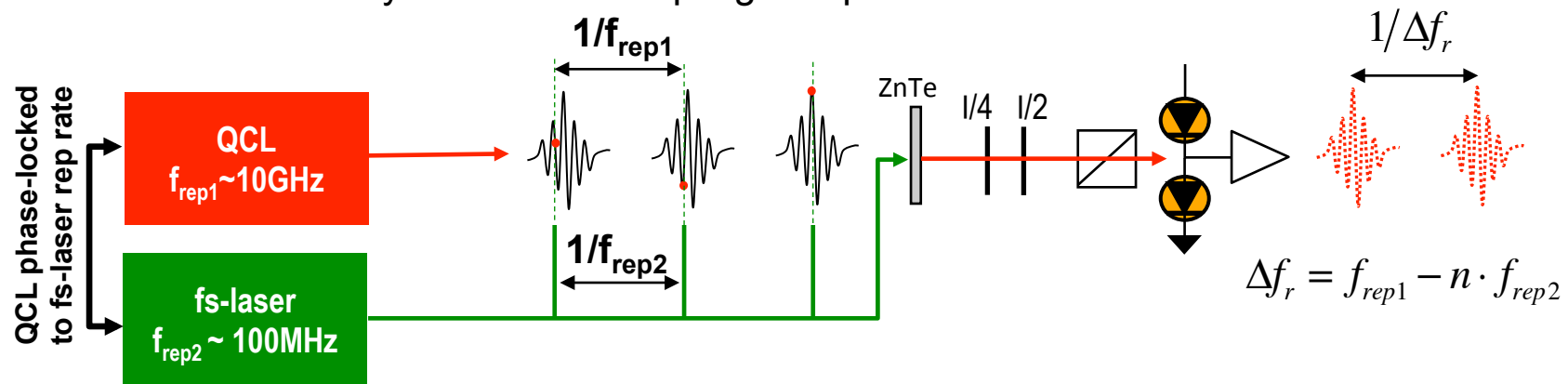
FFG EIP Akademie, 29. Januar 2015

What is (good for) frequency comb ?

set of frequencies evenly spaced on frequency axis

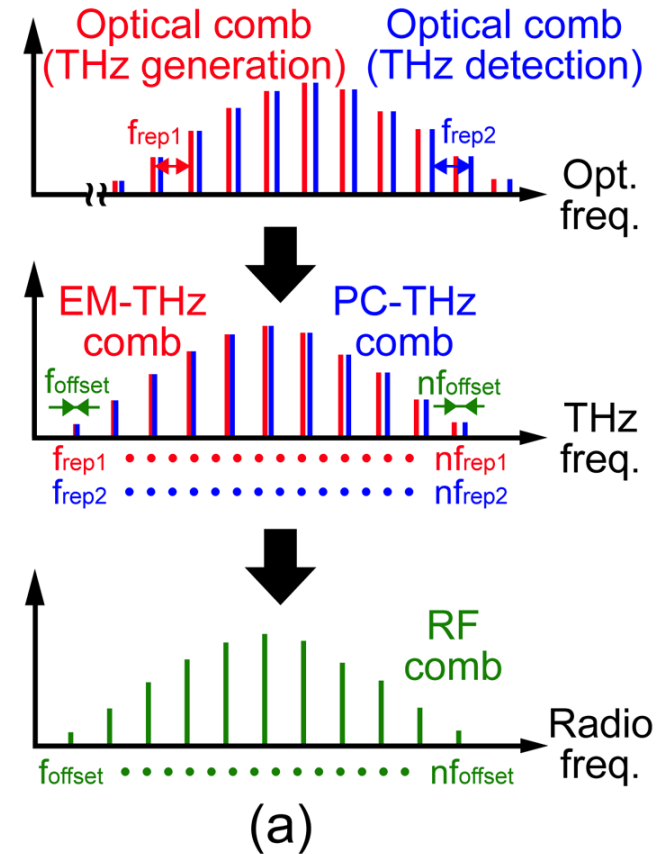
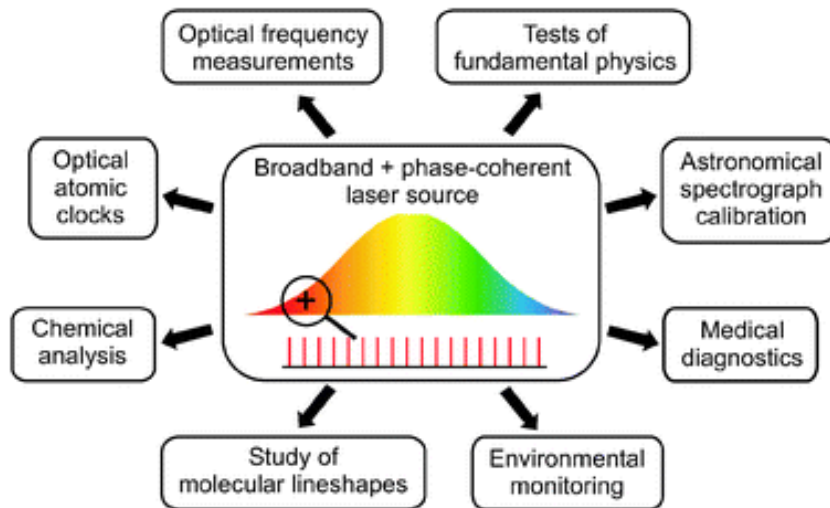


Schematic of the asynchronous sampling setup



What is (good for) frequency comb ?

... for fast and sensitive spectroscopy & beyond



Scient. Rep. 4, 3816 (2014)

... for remote sensing/hyperspectral THz imaging

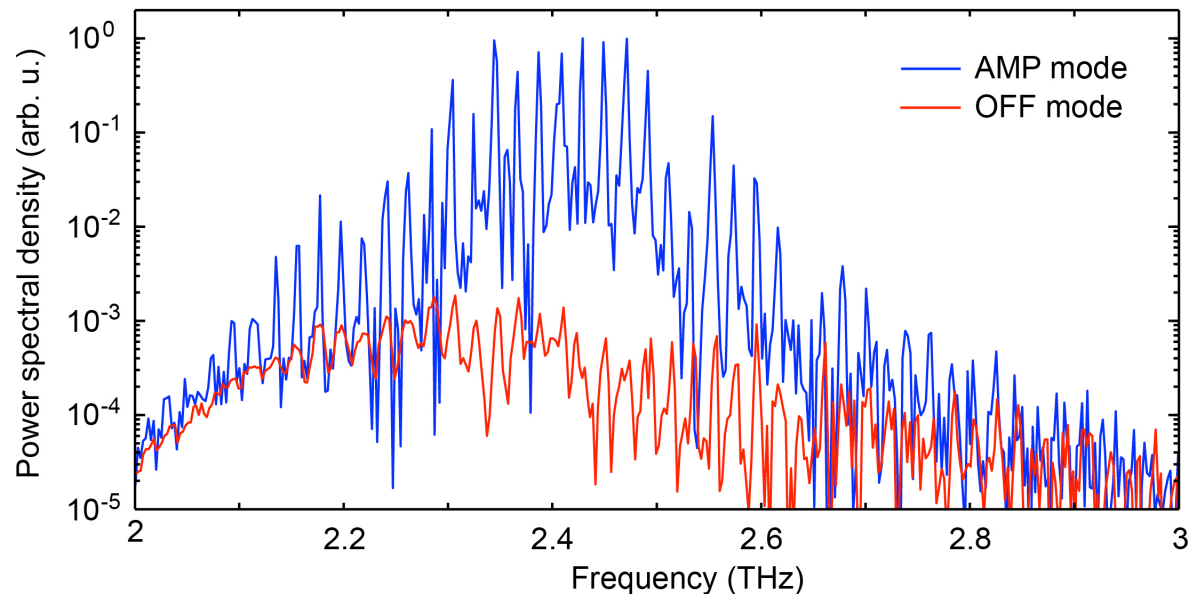
TERACOMB some achievements

- THz QCL laser with emission spanning one octave (1.7 – 3.4 THz)

Nature Photonics 9, 42 (2015)

- THz QCL-based amplifier by 40dB in 400 GHz bandwidth

Optics Express 23, XXXX (2015)



Timeline towards TERACOMB project

Item	Date
Birth of Idea	January 2011
Short proposal submission	May 2011
Full proposal submission	October 2011
Start of GA negotiation	February 2012
GA completed	25 th May 2012
Project start date	1 st June 2012
End date of project	31 st may 2015

Notes on project negotiation phase

Very important

- Consortium Agreement on IPR (back-/fore-ground)
- Risk management plan
- Deliverables & Milestones to control progress

Less important

- planned effort in p/m and budget

Communication rules with POs

Project Officers	
Key	They are there to help you in the project
What they Love	'No problems' (no contractual problems) Paperwork exactly as required Researches understanding/accepting bureaucracy Success stories
What they Hate	Problems without solutions Surprises Being contacted by partners (Coordinator only) Being kept in the dark (or being told every detail)
What they Fear	Contractual problems Delays (if not informed in advance)
Limitations	have to manage up to 50 projects ...

Want to know more?

... visit our homepage !

<http://www.teracomb.eu>