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## EURAMET TC-EM Electricity and Magnetism Brief update and highlights

*Beat Jeckelmann*

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### Outline

- Organisation
- MRA work
- Projects
- Scientific Challenges

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## Organisation of the TC-EM

- New TC-EM chairperson elected (term starting GA 2011):  
**François Piquemal, LNE**
- New SC convenors for 3 SCs
  - SC 1: Electrical quantum standards: **JT Janssen, NPL**
  - SC 2: Low frequency: **Jürgen Melcher, PTB**
  - SC 4: RF and microwave: **Marko Zeier, METAS**

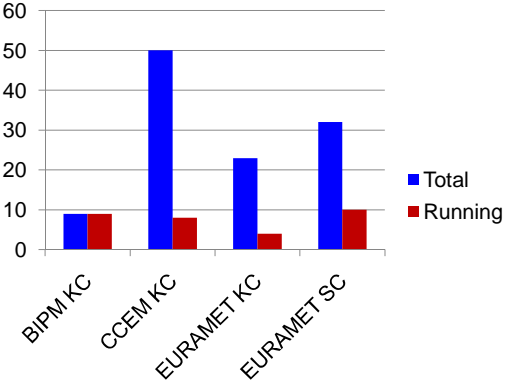
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## MRA work

3635 CMC entries in the KCDB  
in 192 service categories

**Supported by 112 comparisons**



Category	Total	Running
BIPM KC	10	10
CCEM KC	50	10
EURAMET KC	25	5
EURAMET SC	35	10

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## Improvement of MRA processes

Task force prepared catalogue of measures, with the aim to:

- Facilitate the organisation and analysis of comparisons
  - Standard protocol and reports, better involvement of support group, sharing of tasks among several NMIs
- Shorten the duration of comparison projects
  - Limited number of participants, regular reporting

➤ **Workshop will be held during CPEM 12**

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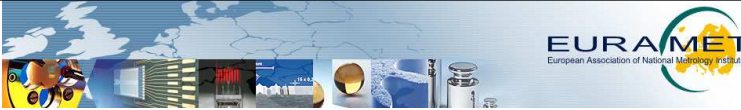


## Improvement of MRA processes (2)

CMCs, Discussion paper presented to the WG RMO of the CCEM:

- Decrease number of CMC entries
  - Re-organisation of service categories, consequent use of matrices
- Improve comparability of entries
  - Better implementation of data-base functionalities in KCDB
- Streamline inter-RMO review process (deadlines, coordinate review work)

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## EMRP: Participation in Call 2010

Rank	SRT No	Title
2	SRT12i:	Electromagnetic characterization of materials for industrial applications up to microwave frequencies
8	SRT11i:	Metrology for advanced industrial magnetics
16	SRT09i:	Metrology for Ultrafast Electronics and High-Speed Communications
	SRT10i:	Metrology for high-speed microelectronics
	SRT08i:	Radio frequency metrology for wireless networks in industrial environments

Three of five proposals selected for funding

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## Preparation for Calls 2011

- **EMRP workshop**, 10 January 2011, attended by delegates from 13 NMIs
- 9 potential topics selected
- Topics elaborated in small working groups; contacts with other TCs and with stakeholders

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## Calibration guide

### Calibration of Oscilloscopes

- Replaces old EA guide
- Discussed and approved by SCs Lf and RF&MW




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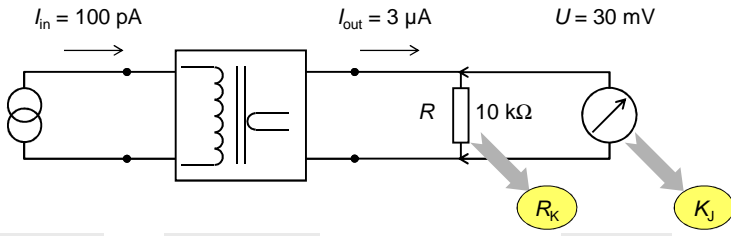


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## Technical Challenges: Some Examples

### 1) Quantum Ampere

Implementation of the new ampere definition



$I_{in} = 100 \text{ pA}$

Current source  
(SET device)

Current  
up-converter  
CCC 1:30 000

$I_{out} = 3 \text{ } \mu\text{A}$


Current-  
voltage  
converter  
Resistor

$U = 30 \text{ mV}$


Voltmeter

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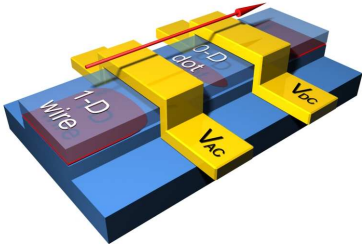
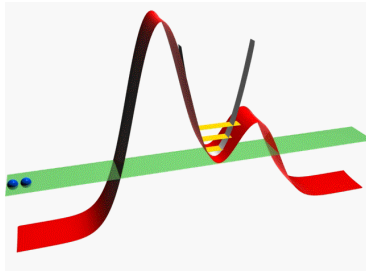
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## Quantum ampere (cont)

Improvement of single electron devices:  
 State-of-the-art **single-parameter semiconductor SET pumps**  
 to generate  $I \approx 160 \text{ pA}$  ( $f \approx 1 \text{ GHz}$ ) with  $u_{\text{rel}} \approx \text{few parts in } 10^7$





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## 2) Impedance


Difficulties in the realization and dissemination of impedance

- Wide range (both value and frequency)
- Resistors, inductors, capacitors
- Realization of a scale difficult
- Transfer between unlike impedances (e.g., RC) *difficult*
- No programmable calibrators available on the market




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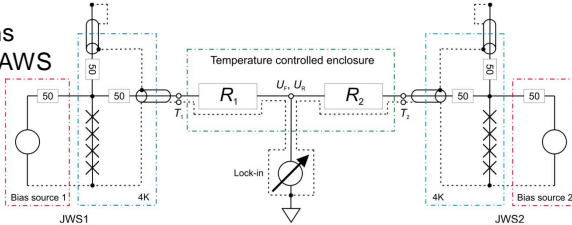
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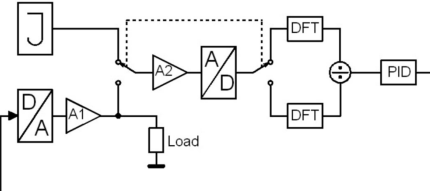
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### Quantum Impedance

Digitally assisted impedance traceability chains  
(PTB: Twoport RR, double JAWS)




Josephson locked synthesizer (METAS)




The principle can be extended to control amplitude ratios and phase of a multiple output digital synthesizer with a single JJ

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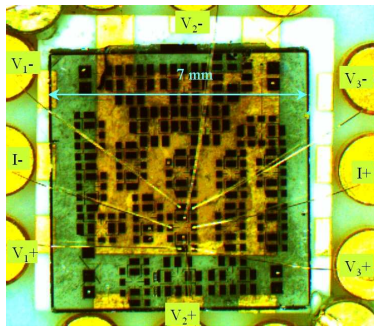


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### 3) Graphene

Impressive progress made recently with epitaxial graphene QHE device (NPL+Universities)


NPL-BIPM collaboration: Testing this universality provides further evidence for  $R_K = h/e^2$  (or not !)

$$R_K \stackrel{?}{=} \frac{h}{e^2}$$



**Preliminary Result:**  
 $(R_{K-GaAs} - R_{K-Graphene}) / R_K = < 1 \times 10^{-9}$

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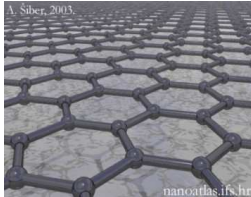


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## Graphene - cont

Graphene has a huge potential

- Develop metrology based on the unique properties of graphene
- Develop metrology for the use of graphene in technology




A. Sberber, 2013.  
nanofab.it/51hr


Objectives for the coming years; based on epitaxial graphene:

- Demonstrate ability to put many working devices on one chip
- Demonstrate working quantum Hall arrays

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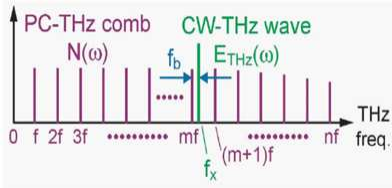


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## 4) THz Metrology

### THz spectroscopy of hazardous substances

- Characterization of Sources and Detectors
- Uncertainty Analysis, precision frequency standards, reference materials and traceability of field strength



PC-THz comb  $N(\omega)$

CW-THz wave  $E_{THz}(\omega)$


THz freq.

Labels:  $0, f, 2f, 3f, \dots, mf, (m+1)f, nf$

Labels:  $f_b, f_x$


Precision frequency measurements based on THz combs (e.g. @ PTB BS)

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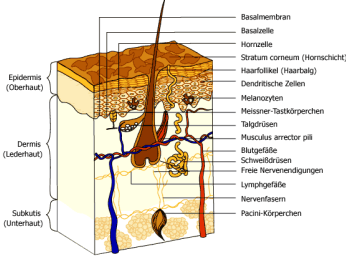


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## THz metrology - cont

### Safe operation of $\mu$ Wave and THz scanners

Dosimetric calculations in skin and verification in skin phantoms, e.g. with thermal imaging




Reliable Field Strength Assessment Procedures




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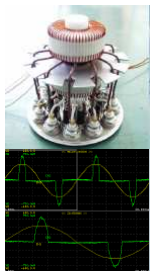
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## Events in 2011


- **Power & energy workshop**  
(dissemination event iMERA-plus project)  
22-23 March 2011, Noordwijk, The Netherlands
- **Joint Dissemination and EURAMET DC and Quantum Metrology Meeting**  
18-20 May 2011, Berlin, Germany





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