



NPL and the Ultrasound and Underwater Acoustics (UUA) Group

Bajram Zeqiri, NPL Fellow & Science Area Leader
4th November 2019.

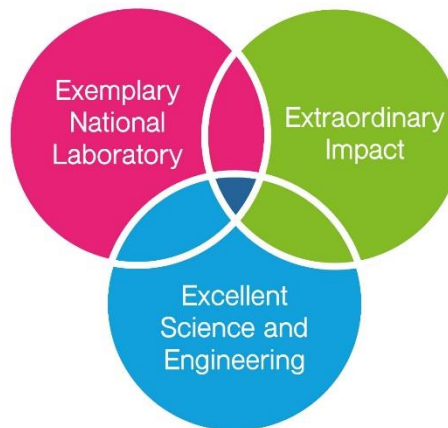
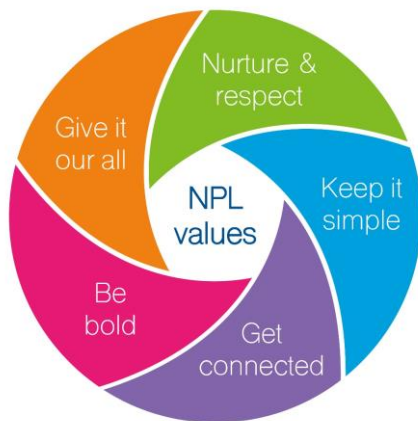
1st Annual International Photoacoustic Standardisation Consortium (IPASC) Meeting.

Presentation plan

- NPL
- Metrology – redefinition of the SI system of units
- Activities in the Medical Ultrasound area

Who we are

- UK's National Metrology Institute (NMI)/ Public Corporation
- Formal Partnership between NPL, BEIS and Universities of Surrey and Strathclyde
- ~1000+ staff with ~200 visiting researchers/year
- 400 laboratories; 36,000 m² of floorspace
- Partner with 200+ organisations and 80+ Universities



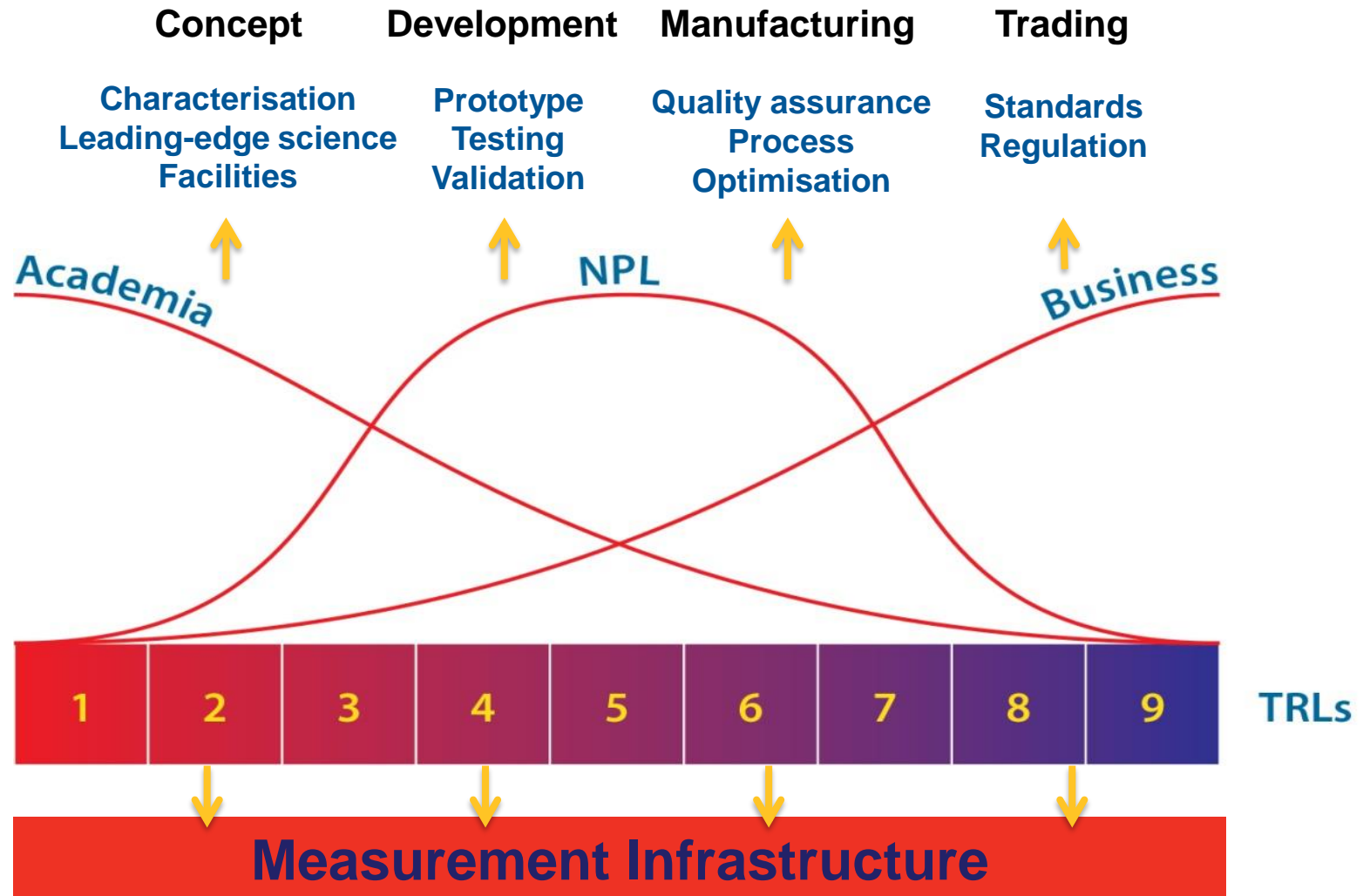
What do we do

- Develop & disseminate UK's measurement standards, ensure they are internationally accepted
- Multidisciplinary R&D and technical services for public and private sector
- Knowledge transfer and advice between industry, government and academia
- Promotion of science and engineering



NPL's position

Supporting innovation





Metrology is the science of measurement

“I often say that when you can **measure** what you are speaking about, and express it in numbers, **you know something about it**; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the state of Science, whatever the matter may be.”

Lord Kelvin, 1883

Bureau International des Poids et Mesures – the intergovernmental organization through which Member States act together on matters related to measurement science and measurement standards.

ABOUT US WORLDWIDE METROLOGY INTERNATIONAL EQUIVALENCE SI UNITS

26th meeting of the CGPM: 13-16 November 2018

Meeting logistics

- Attendance and registration
- Provisional timetable
- Timetable for open session on 16th November
- Attendance policy
- Map/location
- Hotels in Versailles



Working documents

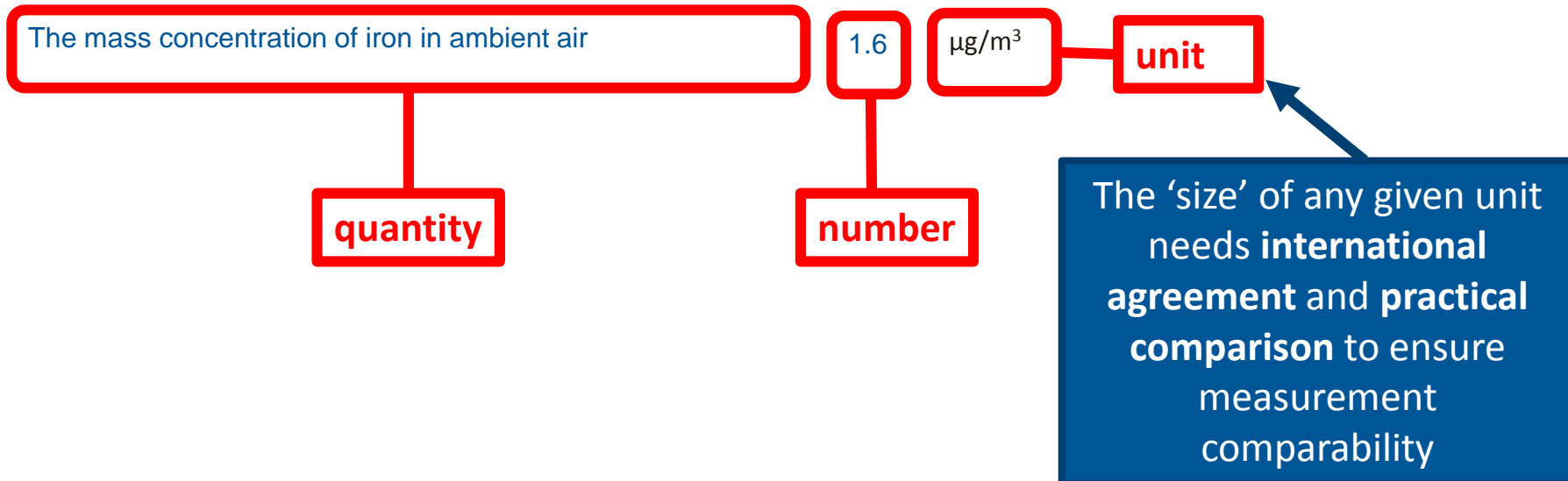
- Draft BIPM Work Programme 2020-2023 (Version for comment)
- BIPM strategic plan
- Convocation
- Draft Resolutions
- Letter from the CIPM Secretary inviting nominations for the election of the CIPM

- Final approval by CGPM in November 2018
- Implemented on 20 May 2019, World Metrology Day



Measurement units

- All of practical science, technology and engineering involves measurement
- When presenting the result of a measurement, the value of a quantity is expressed as the product of a numerical value and a unit: $Q = \{Q\}[Q]$



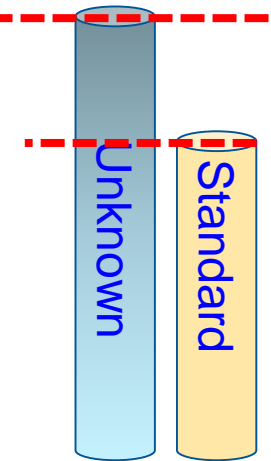
The Results of Metrology

- Generates systems and frameworks for quantification and through these underpins consistency and assurance in all measurement
- Gives a quantified level of confidence in the measurement through an uncertainty statement
- Provides a measurement infrastructure which is **stable** over time, **comparable** between locations, and **coherent**, allowing measurements of different properties using different methods to be combined (without scaling factors)
- Removes barriers to trade, improves efficiency and competitiveness, enables technological development, encourages global agreement and collaboration



Measurement is...

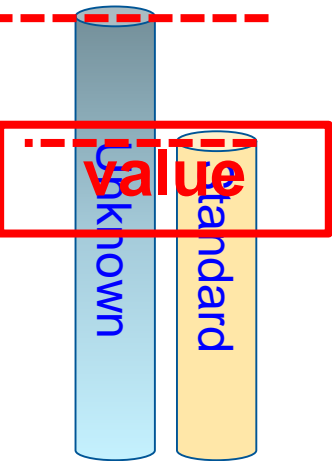
Quantitative Comparison



**...of an unknown quantity
with a standard quantity**

Measurement is...

*Technically a measurement
has three components*

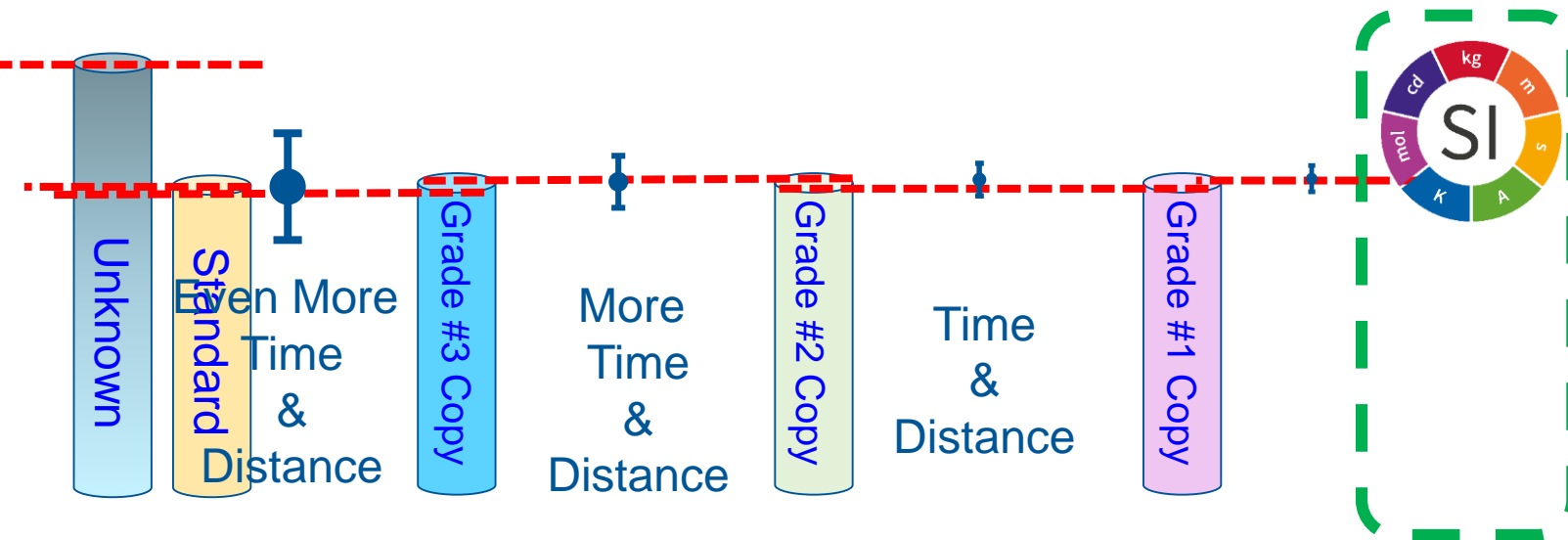


unit

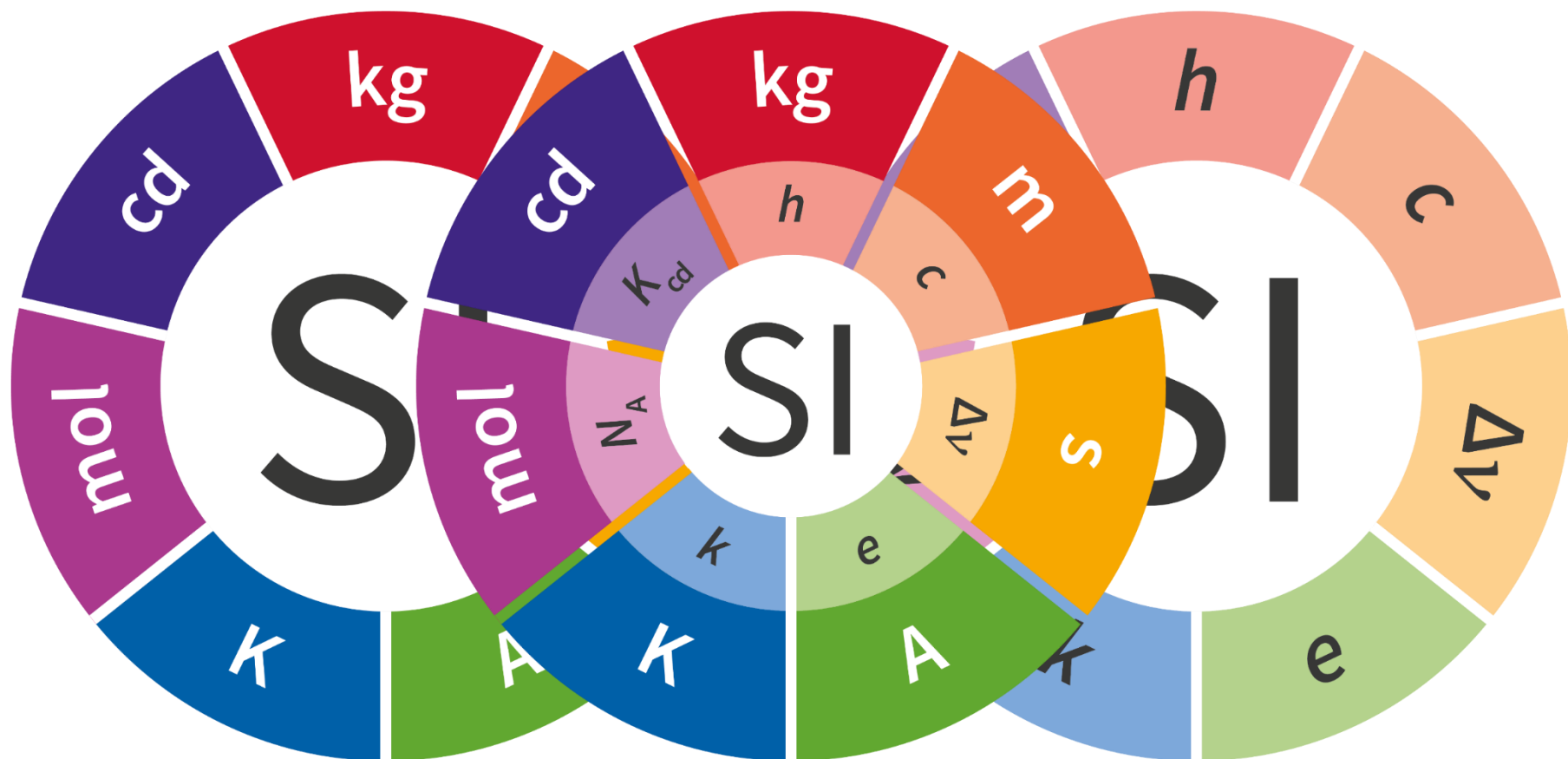
uncertainty

Measurement is...

Quantitative Comparison



The New International System of Units



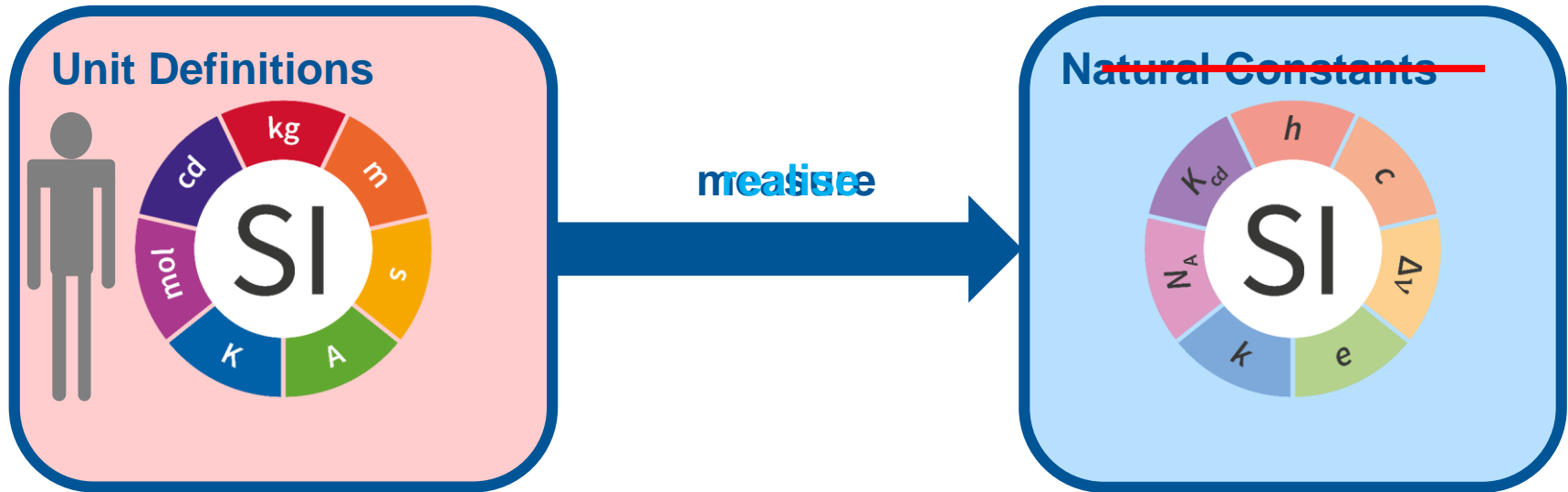
The SI *will* be the system of units in which the following constants have these exact values.



Symbol	Constant	Numerical Value	Unit
$\Delta\nu_{Cs}$	the unperturbed ground state hyperfine transition frequency of the caesium 133 atom	9 192 631 770	Hz
c	the speed of light in vacuum	299 792 458	m s ⁻¹
h	the Planck constant	$6.626\,070\,15 \times 10^{-34}$	J s
e	the elementary charge	$1.602\,176\,634 \times 10^{-19}$	C
k	the Boltzmann constant	$1.380\,649 \times 10^{-23}$	J/K
N_A	the Avogadro constant	$6.022\,140\,76 \times 10^{23}$	mol ⁻¹
K_{cd}	the luminous efficacy of monochromatic radiation of frequency 540×10^{12} hertz	683	lm/W.

SI Base Units and Natural Constants

Unit Definitions
in terms of



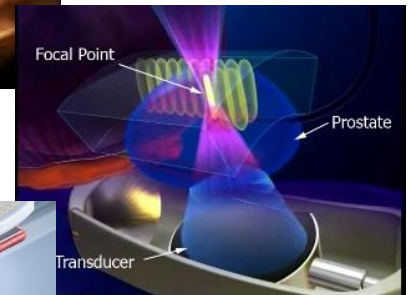
MEDICAL ULTRASOUND AT NPL

Overview – Medical Ultrasound

- Ultrasound is the 2nd most commonly applied diagnostic imaging in the UK after X-rays
 - In the UK, 3 million obstetric and 8.5 million non-obstetric ultrasound imaging scans are carried out annually, growing at 10% each year

We provide:

*traceability to the ultrasound community:
ensuring safe and effective application for a
range of clinical procedures, both diagnostic and
therapeutic; supporting accelerated development
of innovation and delivering step-changes in
medical ultrasound, through the provision of
user-focused measurement capability*



Activity aligned with NPL Life Sciences and Health Sector Strategy

Strategic growth areas in medical ultrasound at NPL:

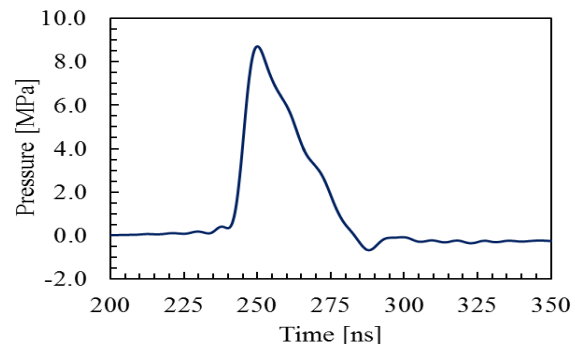
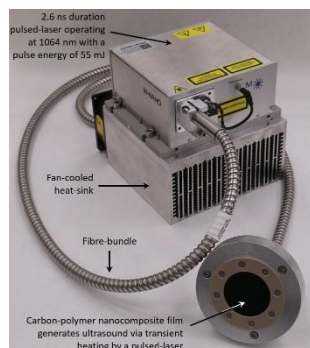
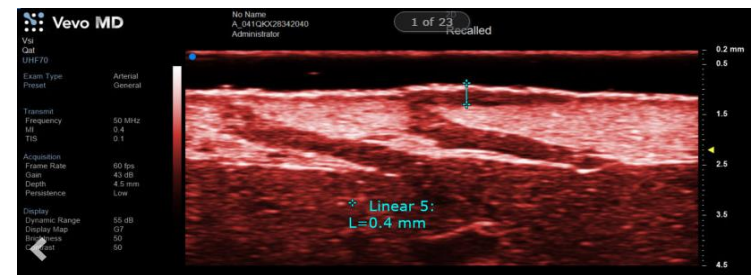
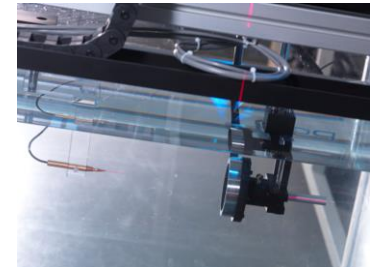
- **Quantitative Imaging (QI) of tissue**
 - strong need to develop a metrological infrastructure that generates confidence with clinical users regarding the accuracy (*QIBA*).
 - via ultrasound systems which image the viscoelastic properties of tissue (stiffness).
 - development of phase-insensitive UCT technology.
 - photoacoustic imaging and PAM (Aoife Ivory and Anant Shah).
- **Metrology for high resolution ultrasound scanners**
 - requires photoacoustic sources capable of high frequency generation.
 - primary standards for realising the acoustic pascal to 100 MHz.
- **Support rapid uptake and clinical acceptance of therapeutic ultrasonic applications, such as High Intensity Focussed Ultrasound**
 - challenges due to very high intensities and acoustic pressures.
 - lack of reliable acoustic property data for tissue.
 - underpinning patient-specific treatment planning through reliable validation and QA.

Hydrophone calibration (Srinath Rajagopal)

Hydrophones are used to quantify the acoustic output of medical ultrasound equipment and NPL's work has direct impact on assessment of equipment safety and effectiveness

Recent highlights include:

- CCAUV.U-K4 hydrophone international key-comparison in the frequency range 0.5 – 20 MHz involving PTB, NIM, NMIJ and INMETRO
- Photoacoustic source material developed based on polymer nanocomposites.
- Unipolar ultrasound pulses of amplitude up to 8 MPa with useable bandwidth of 80 MHz realised.
- Develop a portable photoacoustic source to enable application on primary standard.



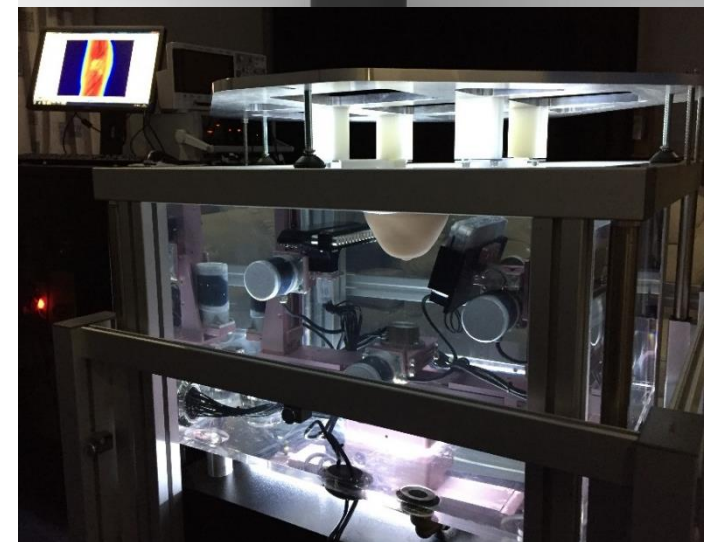
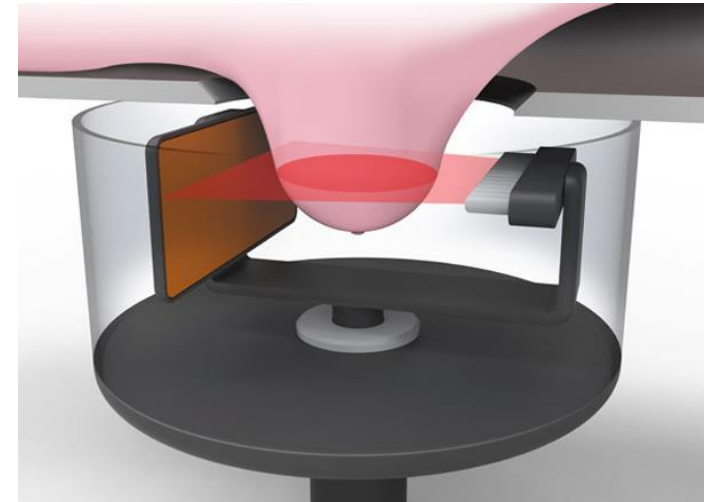
Laser generated ultrasound pulse

- Collaborated to develop high frequency calibration capability for high resolution medical ultrasound scanners.

Phase-insensitive (PI) Ultrasound Computed Tomography (Dan Sarno)

Within the UK, over 60,000 women are diagnosed with breast cancer per year:-

- X-ray Mammography is difficult to apply in younger women with dense breast tissue. These have an increased breast cancer risk.
- about 30% of all mammograms are of questionable value with unwanted artefacts.
- only one in three biopsies are found to be malignant meaning that 92,000 unnecessary procedures are carried out, at a cost of ~£35 million to the NHS.
- NPL, University Hospitals Bristol, Precision Acoustics, Acoustic Polymers Ltd and DesignWorks have developed a prototype clinical system for a new breast screening technique - using ultrasound computed tomography (UCT).
- made possible through a new phase-insensitive ultrasound detector.





Precision Measurement...

...brings the world into focus

Enjoy the meeting!