Design and realisation of a simple, rapid Beam Plotting System for medical ultrasound fields

Christian Baker
National Physical Laboratory
Teddington
Middlesex
TW11 0LW

40th Annual Symposium of the Ultrasonic Industry Association
Wolfson Medical School, University of Glasgow, UK, 23 May 2011

Presentation plan

NPL
National Physical Laboratory

- The Problem
- Requirements of a Solution
- Our Design & Implementation
- Measurement Procedure
- Testing
- Future Improvements

The Problem (1/3)

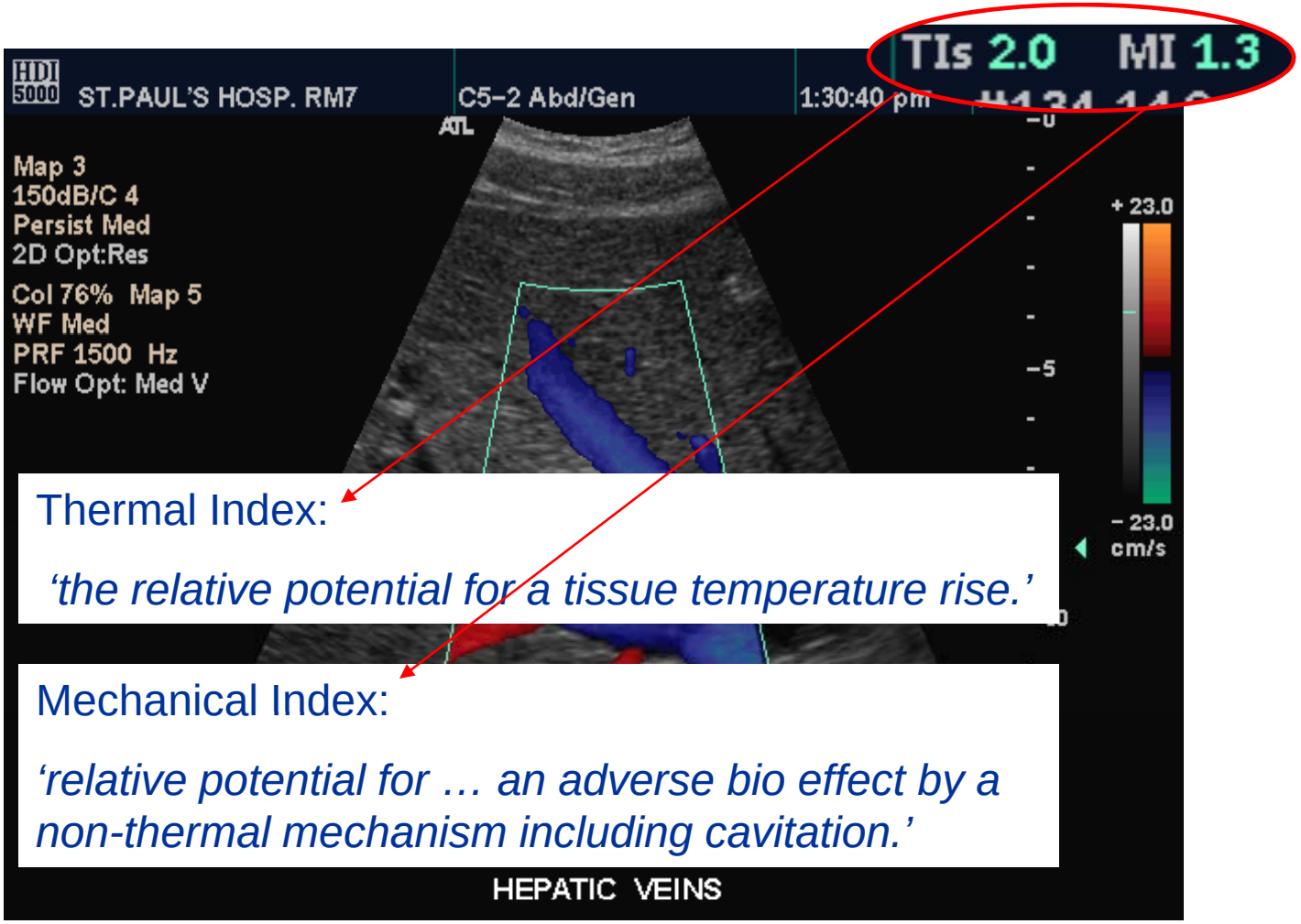
- Number of ultrasound scans carried out each year is increasing, systems becoming more complex
- Safety committees recommend QA procedures
- QA of medical ultrasound devices is time consuming and expensive
- Many hospitals find it difficult to undertake QA measurements

The Problem (2/3)

- BMUS Safety Guidelines Recommend periodic checking of acoustic output:

  - *‘There should be independent checks that the displayed TI and MI values are accurate’*

The Problem (3/3)



System Requirements (1/5)

NPL National Physical Laboratory

- Rapid
- Easy to use
- Portable
- Cost effective
- No need to submerge device under test

System Requirements (2/5): Scanned and Non-Scanned Modes

National Physical Laboratory

System Requirements (3/5): Mechanical Index

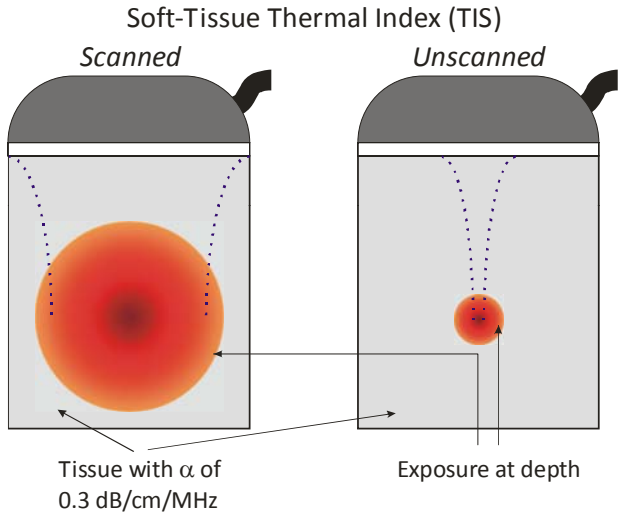
NPL National Physical Laboratory

$$MI = \frac{p_{r.3}(\text{at } z_{sp})}{\sqrt{f}}$$

System Requirements (4/5): Thermal Index (Soft Tissue)

- Scanned / At Surface Non-Scanned

$$TIS_{as,ns} = \frac{P_{1x1}\, f_{awf}}{210\,\text{mW MHz}}$$



- Below Surface Non-Scanned

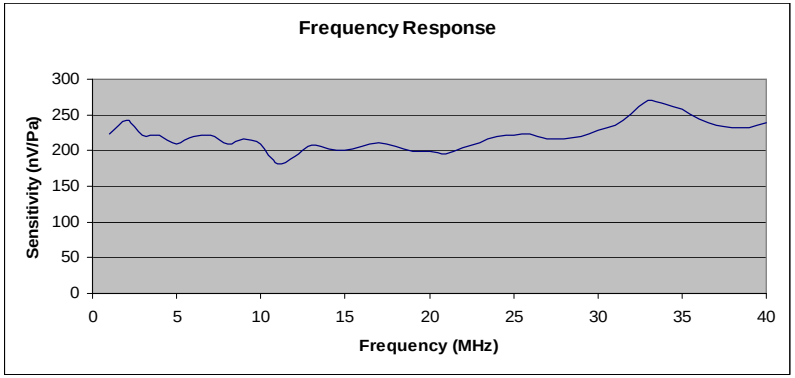
$$TIS_{bs,ns} = \min\left[\frac{P_{\alpha}(Z_{s,ns})\, f_{awf}}{210\,\text{mW MHz}}, \frac{I_{spta,\alpha}(Z_{s,ns})\, f_{awf}}{210\,\text{mW cm}^{-2}\,\text{MHz}}\right]$$

System Requirements (5/5): Required Measurements

- Axial scan (p_r, I_{ta})
- Pulse repetition rate / frame rate & pulses per frame
- Acoustic working frequency
- Output power and bounded square power

Design & Implementation (1/5): Pressure Measurement Sensor

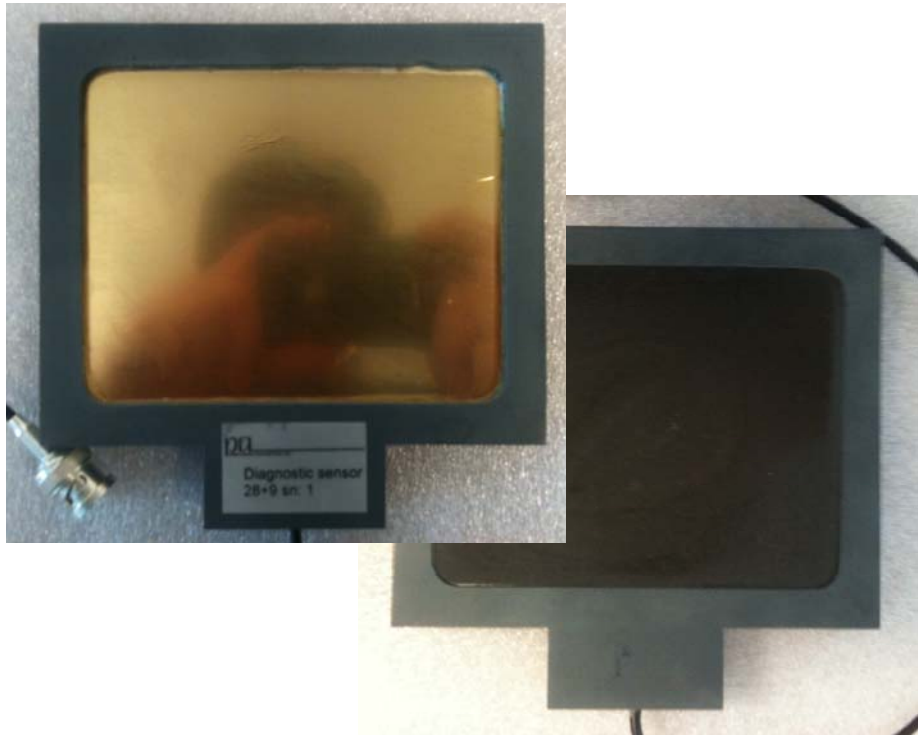
- Onda HGL-0200 Hydrophone & AG-2020 Preamp
- PicoTech PicoScope 4224 PC Oscilloscope
- LabVIEW Software on a Laptop PC



Design & Implementation (2/5): Power Measurement

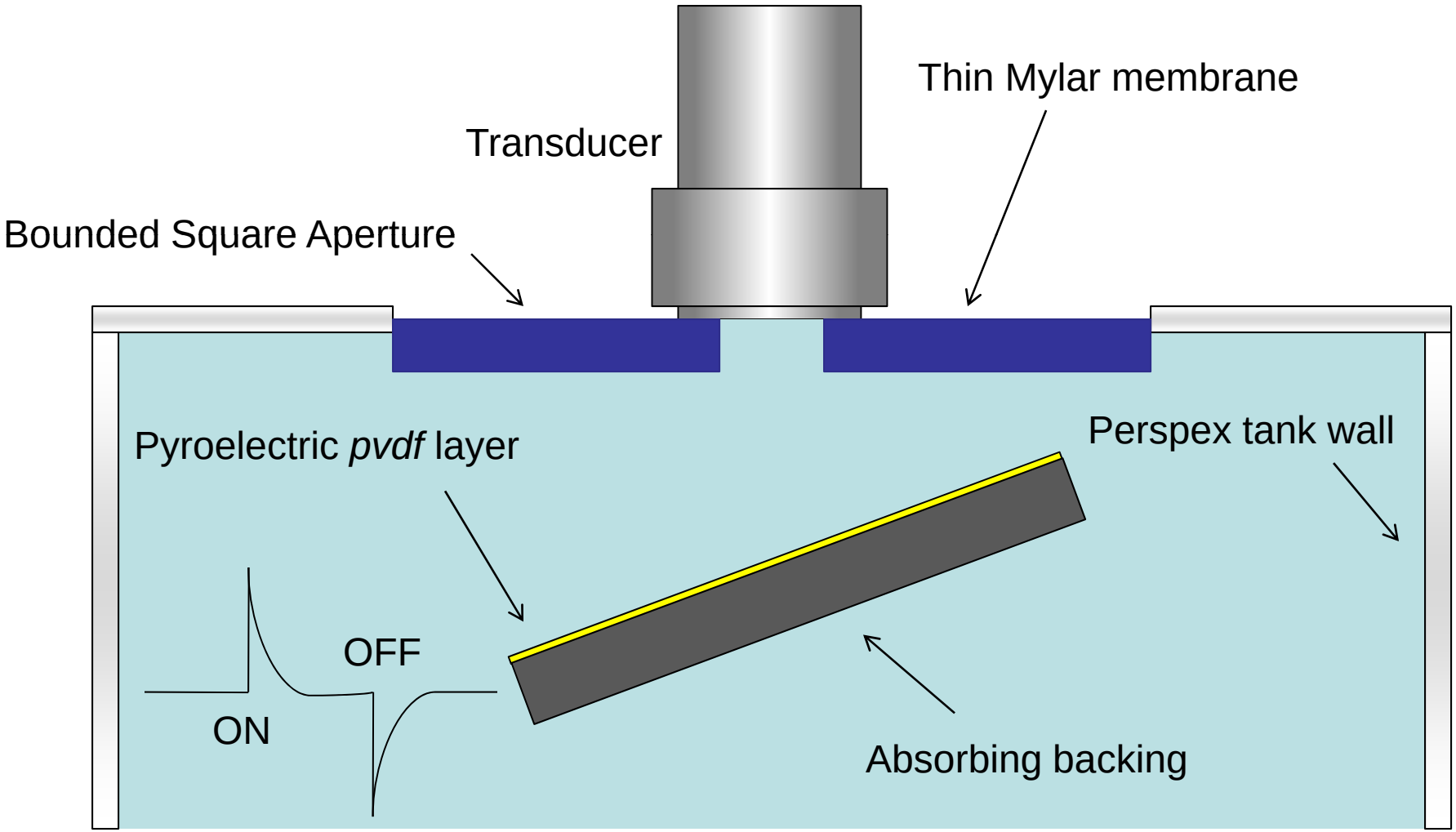
NPL National Physical Laboratory

- Thermal method
- Pyroelectric effect of thin (52 μm) *pvdf* layer
- Backed by a thick, highly absorbent layer (75 dB cm^{-1} at 1MHz)
- Output proportional to rate of change of temperature of *pvdf*

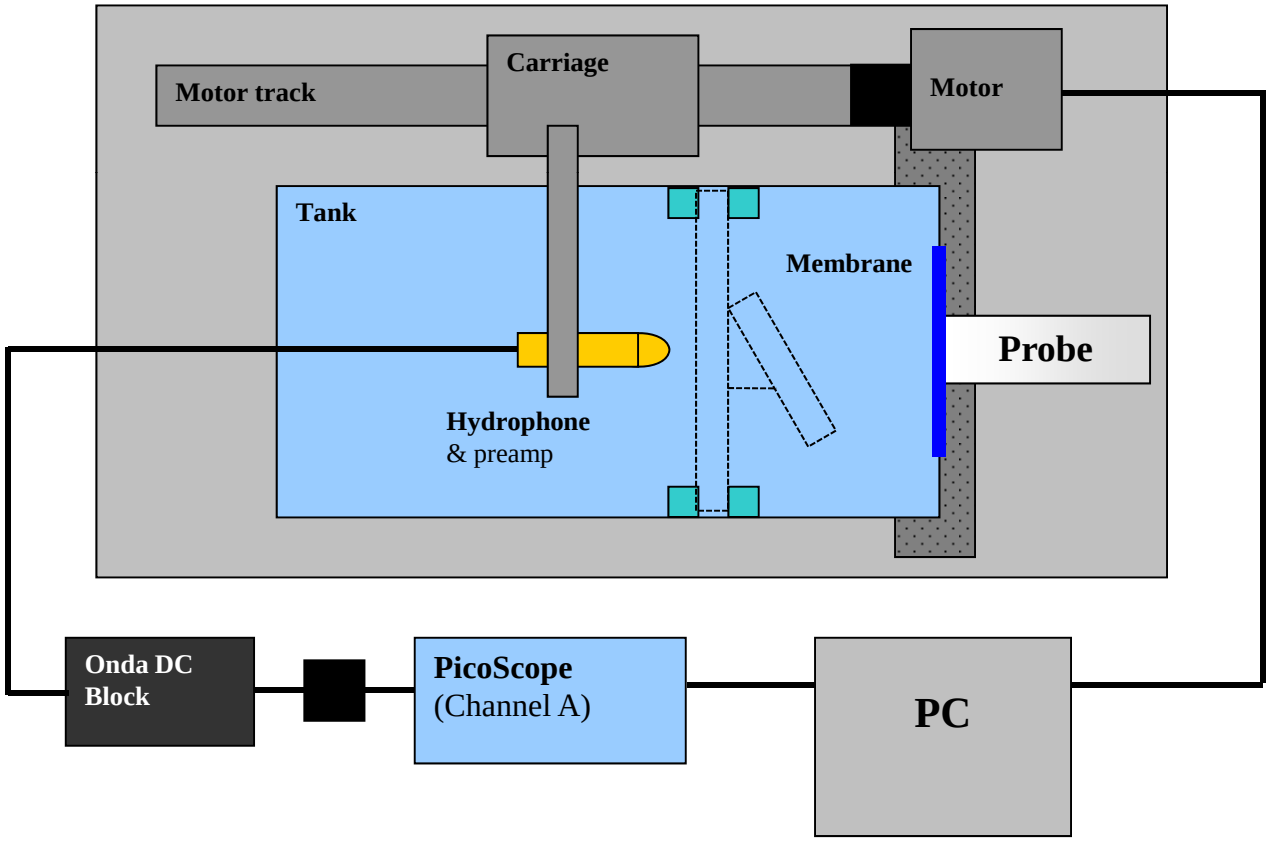


B.Zeqiri, P.N. Gelat, J. Barrie and C.J. Bickley, "A novel pyroelectric method of determining ultrasonic transducer output power: device concept, modelling and preliminary studies," IEEE Trans. Ultrason. Ferroelect. Freq. Control., vol. 54, pp. 2318 – 2330, 2007.

Design & Implementation (3/5): Power Measurement

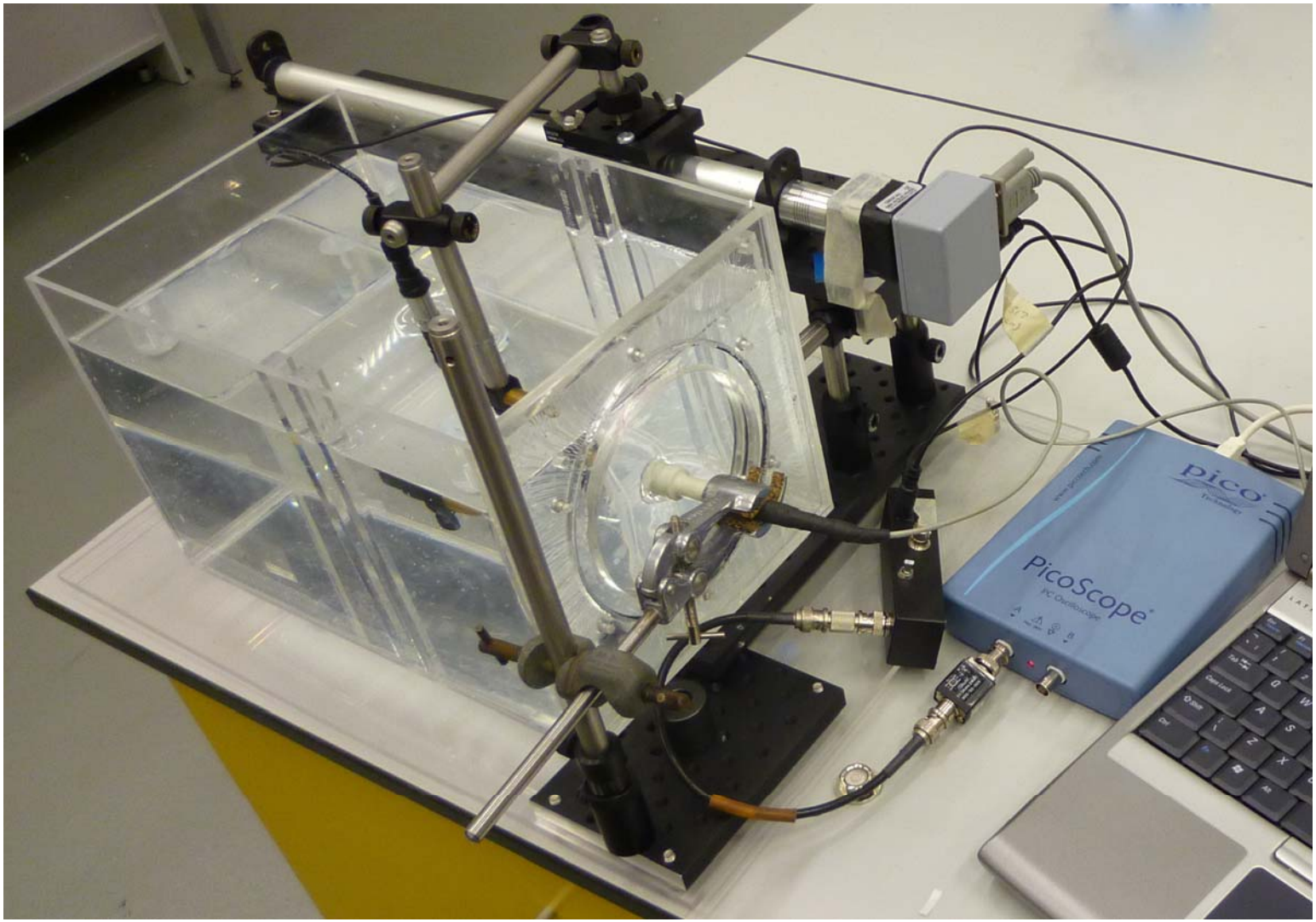


Design & Implementation (4/5): Diagram



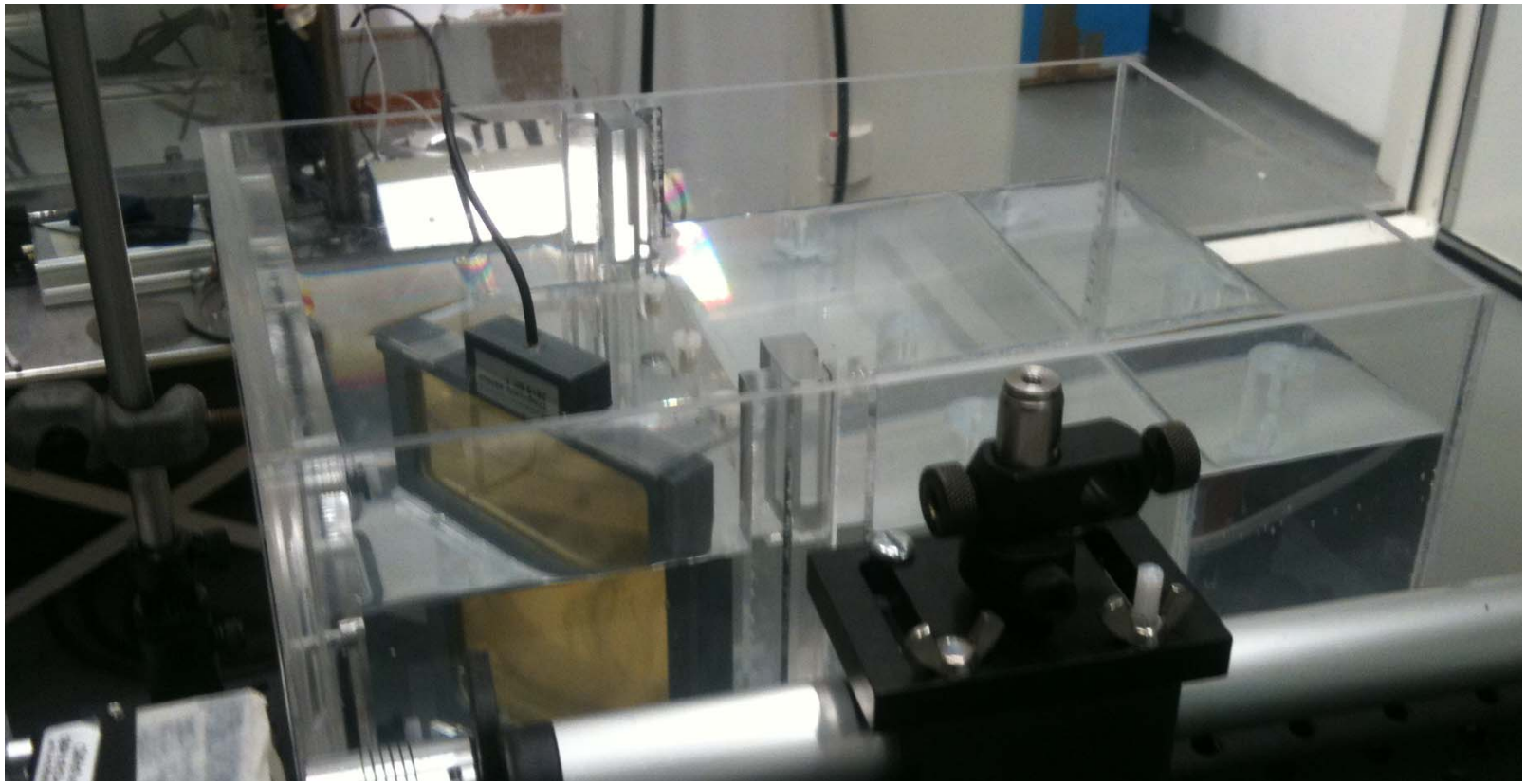
Design & Implementation (5/5): Photos

NPL National Physical Laboratory

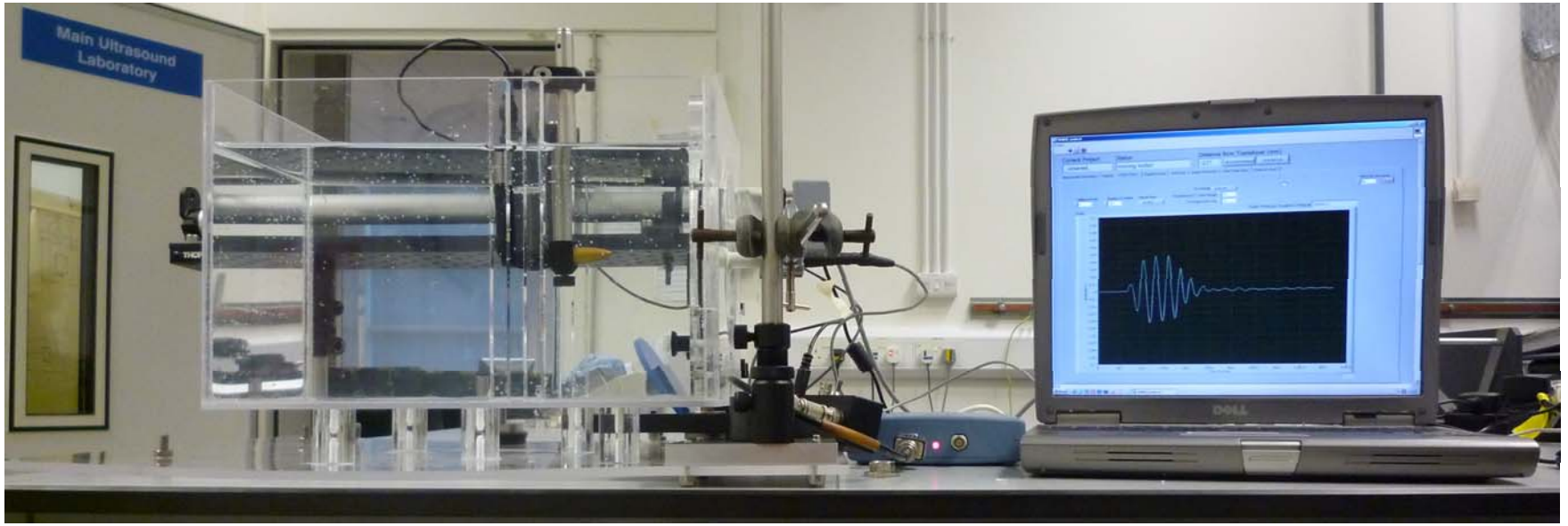


Design & Implementation (5/5): Photos

NPL
National Physical Laboratory

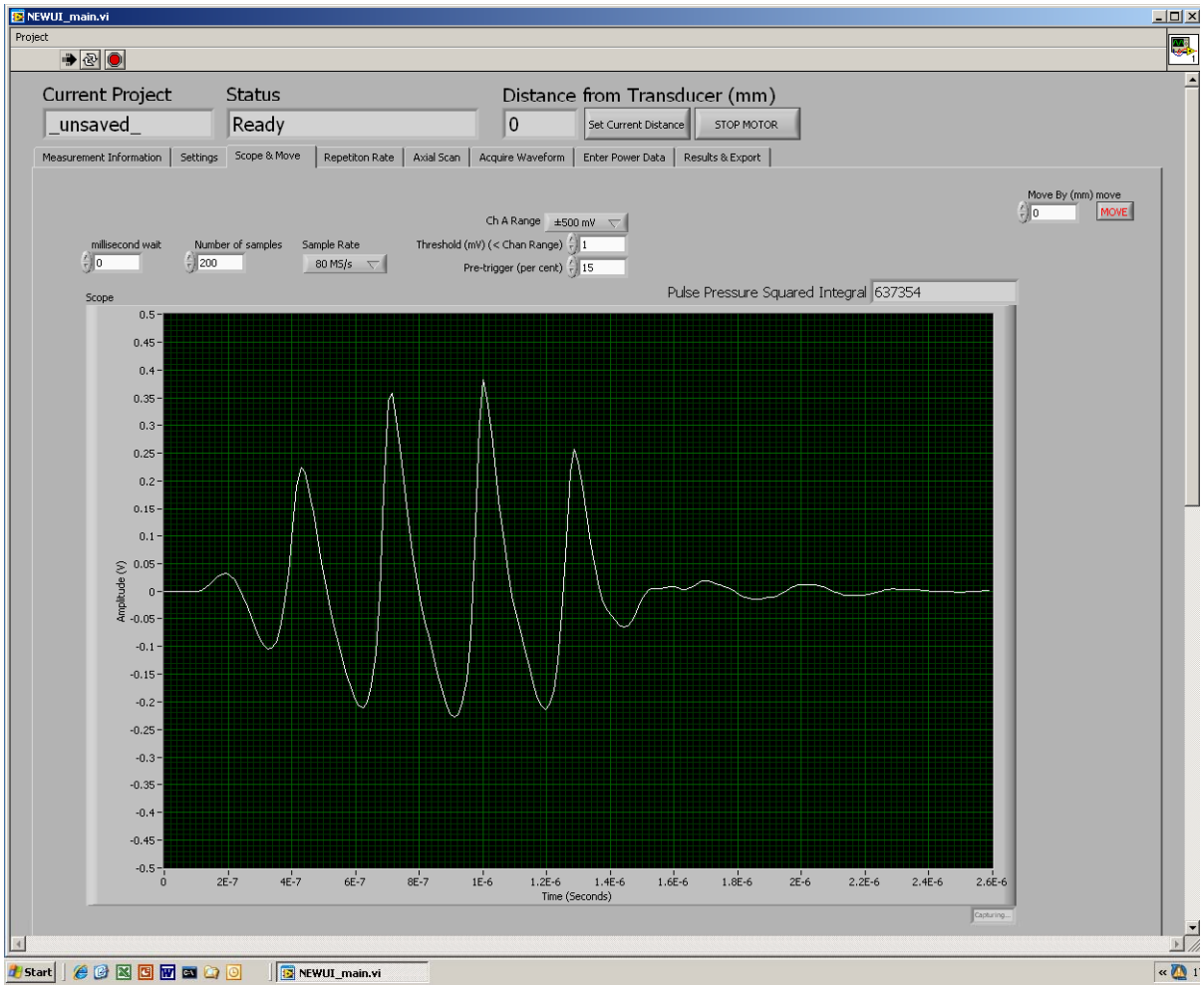


Design & Implementation (5/5): Photos



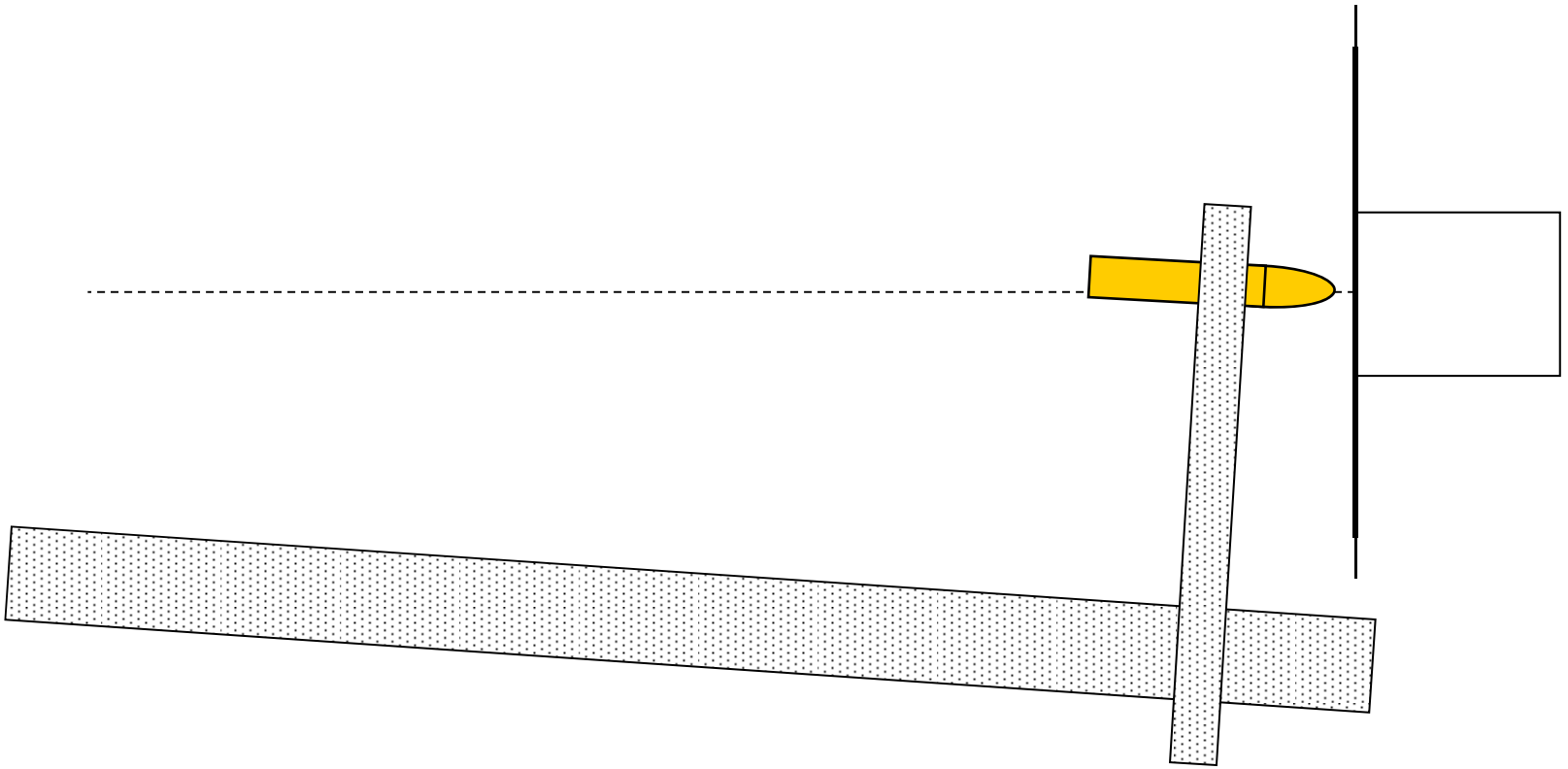
Measurement Procedure (1/10): 1) Alignment

National Physical Laboratory



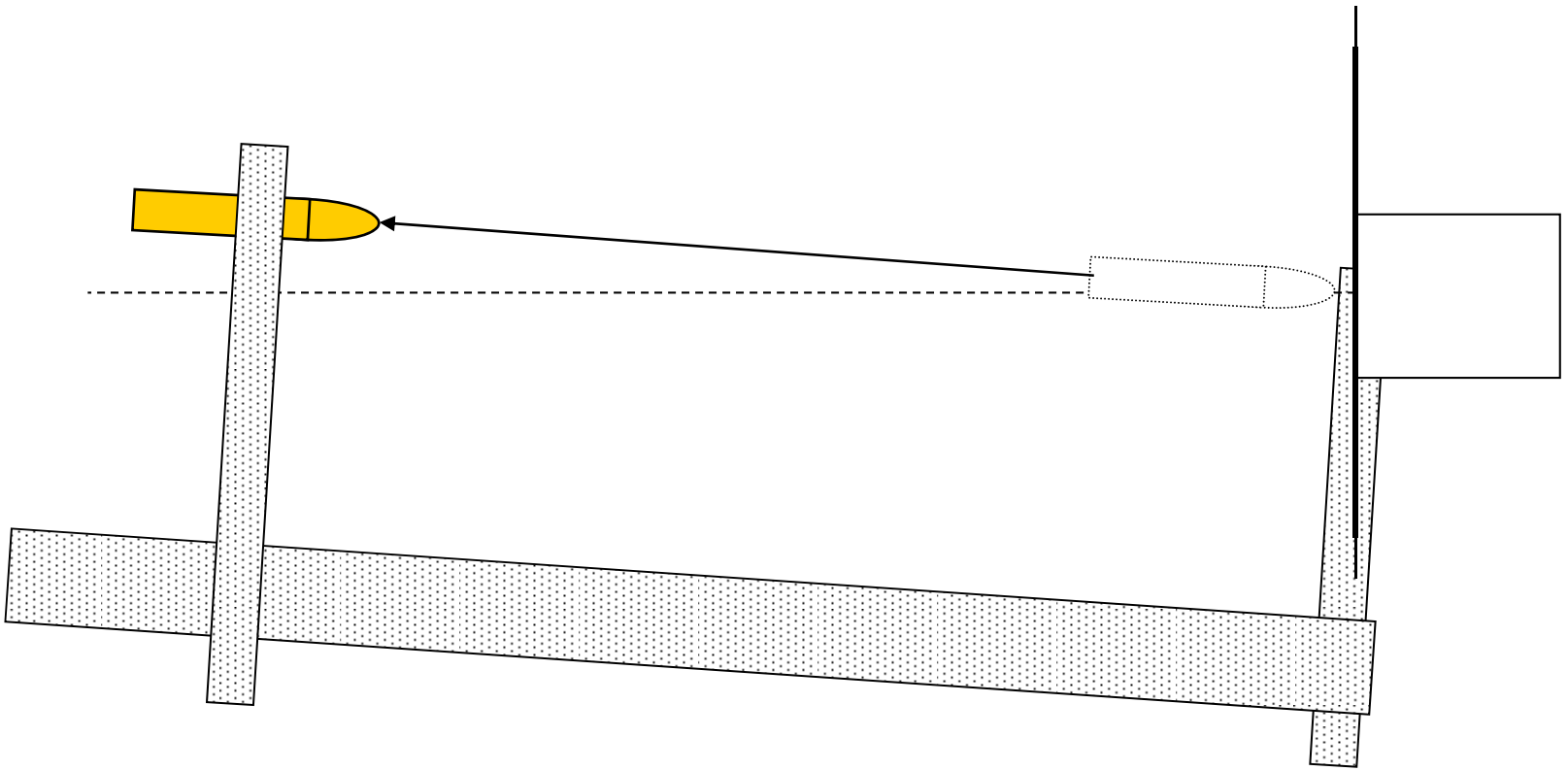
Alignment → PRR/FRR → Axial Scan → Frequency → Power → Calculations

Measurement Procedure (2/10): 1) Alignment



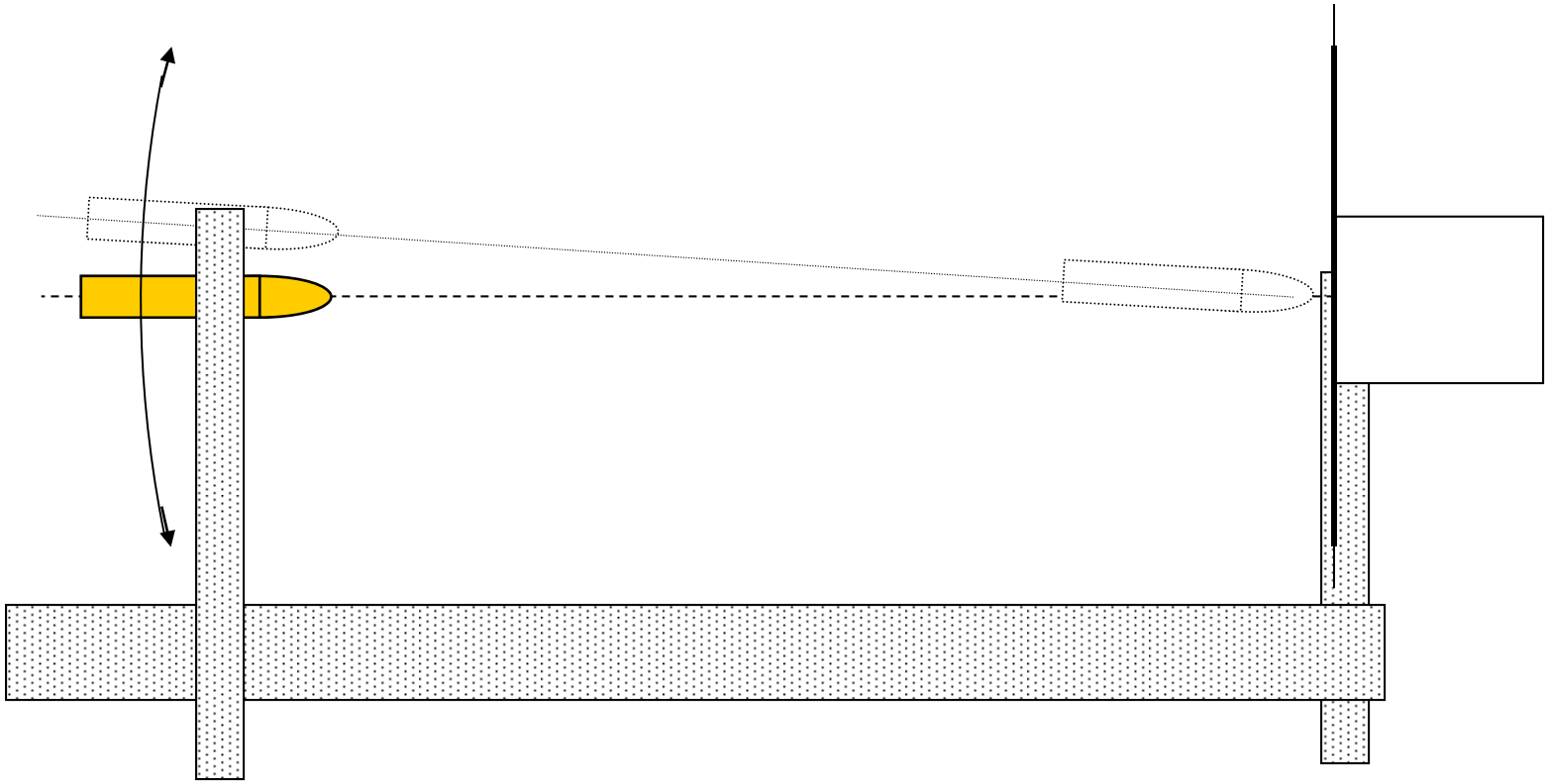
Alignment → PRR/FRR → Axial Scan → Frequency → Power → Calculations

Measurement Procedure (2/10):
1) Alignment



Alignment → PRR/FRR → Axial Scan → Frequency → Power → Calculations

Measurement Procedure (2/10): 1) Alignment

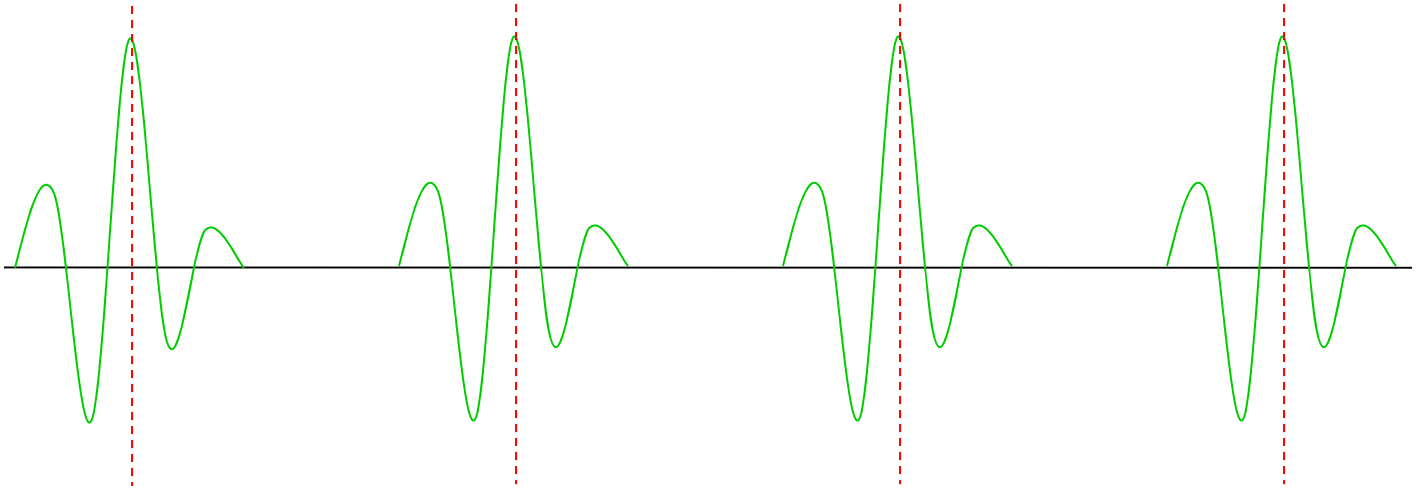


Alignment → PRR/FRR → Axial Scan → Frequency → Power → Calculations

Measurement Procedure (3/10):
2) Pulse / Frame Rate Measurement

NPL National Physical Laboratory

- Non-Scanned Mode

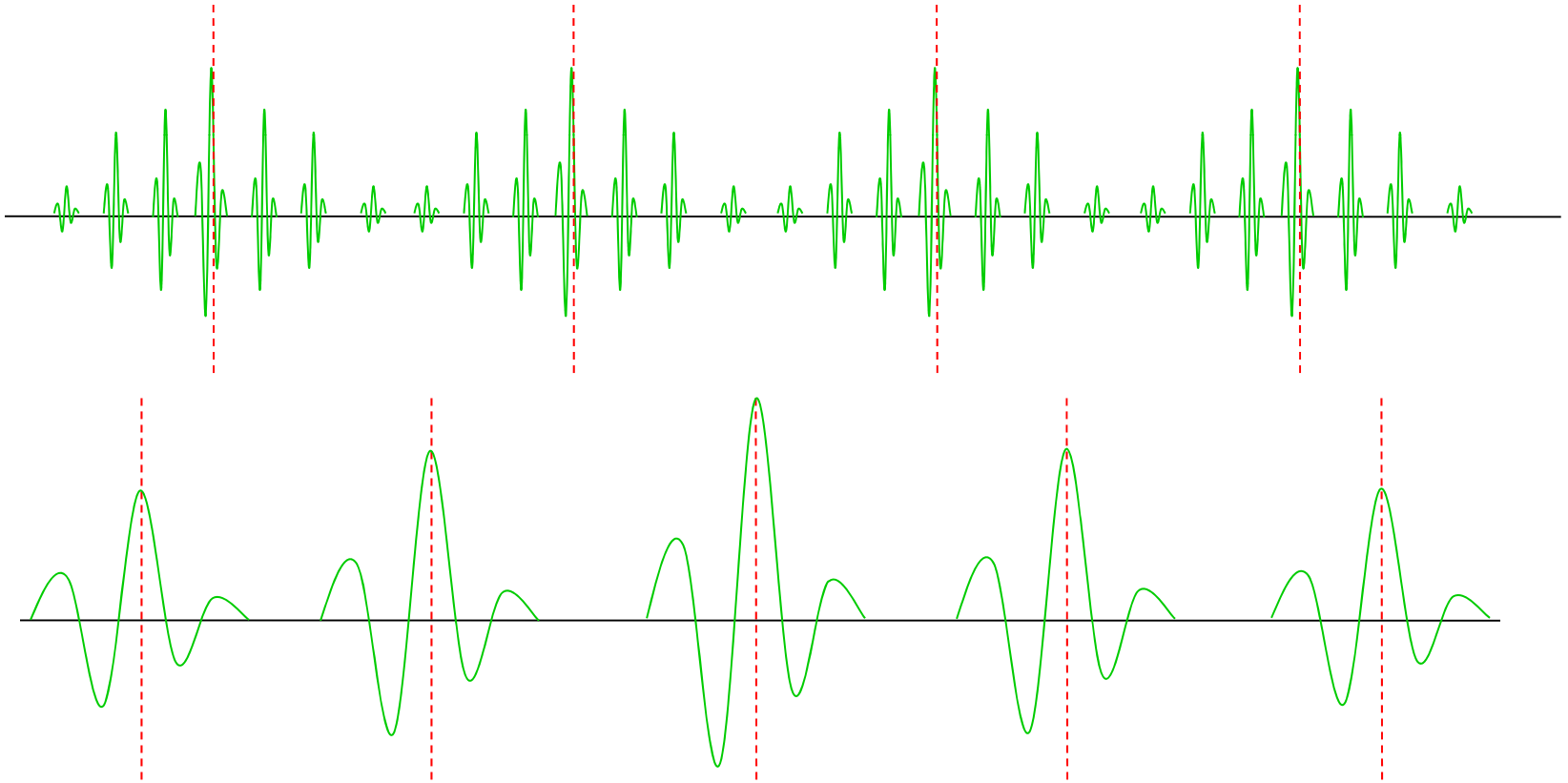


Alignment → PRR/FRR → Axial Scan → Frequency → Power → Calculations

Measurement Procedure (4/10):
2) Pulse / Frame Rate Measurement

NPL National Physical Laboratory

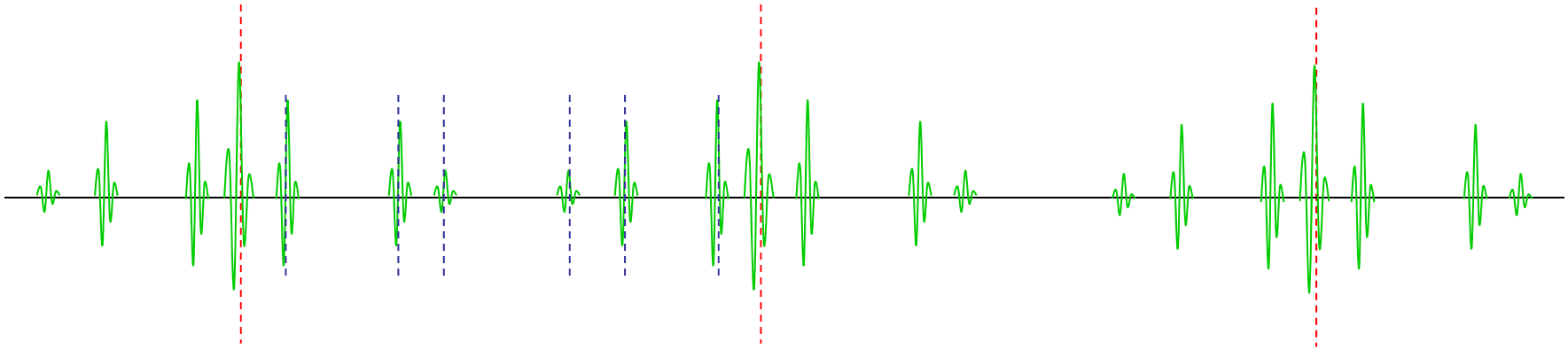
- Scanned Mode with Constant Pulse Rate



Alignment → PRR/FRR → Axial Scan → Frequency → Power → Calculations

Measurement Procedure (5/10):
2) Pulse / Frame Rate Measurement

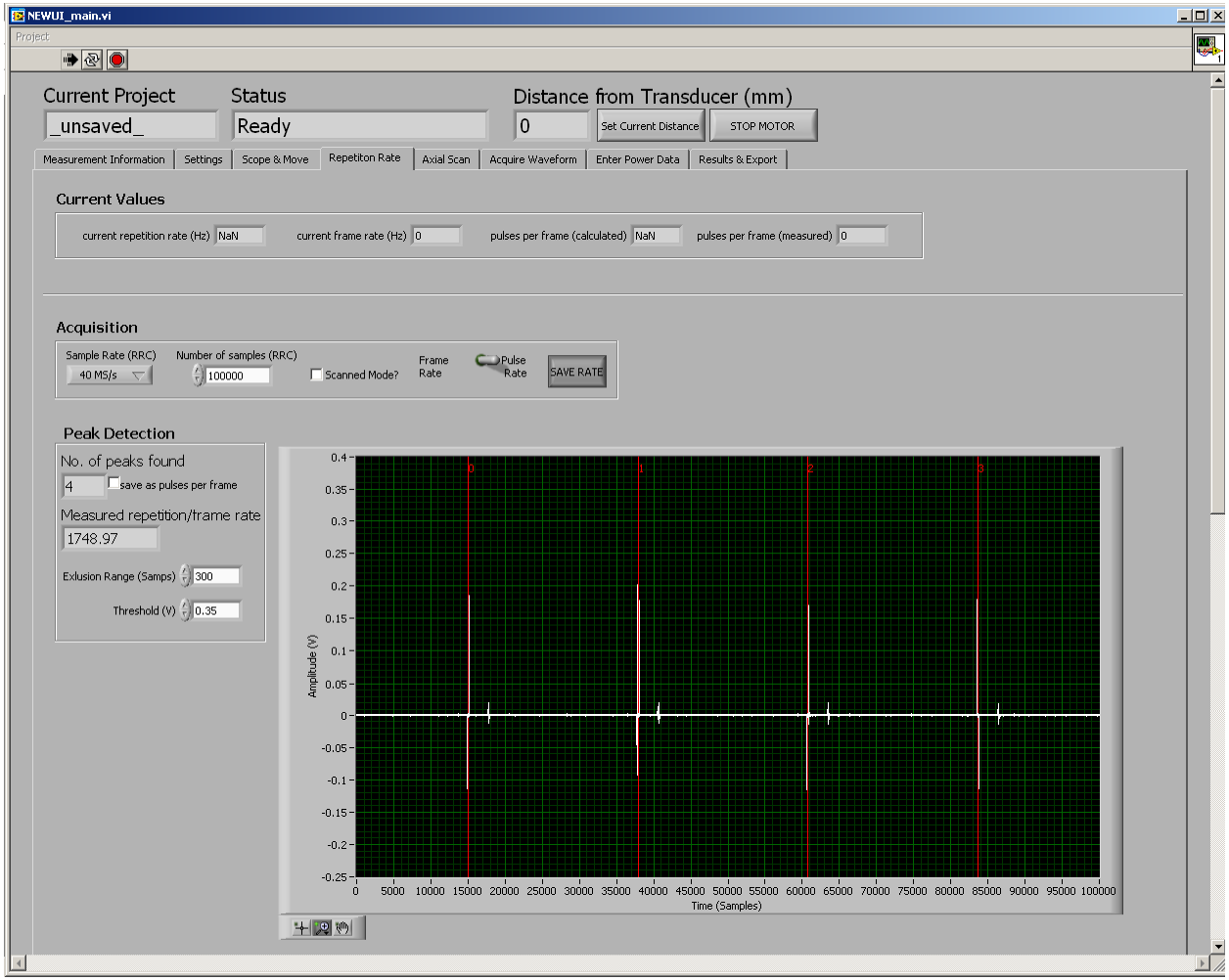
- Scanned Mode with Varying Pulse Rate



Alignment → PRR/FRR → Axial Scan → Frequency → Power → Calculations

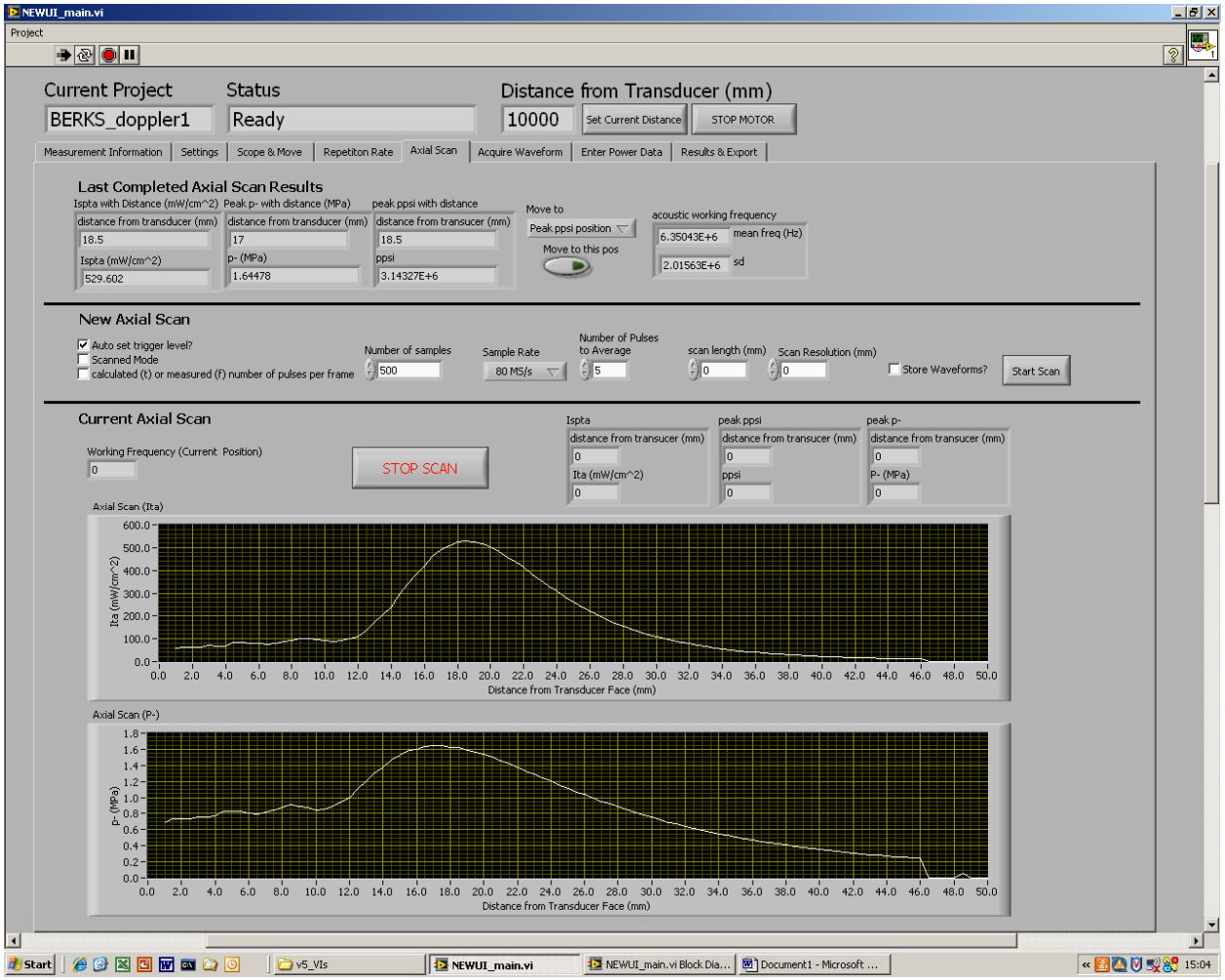
Measurement Procedure (6/10):
2) Pulse / Frame Rate Measurement

National Physical Laboratory



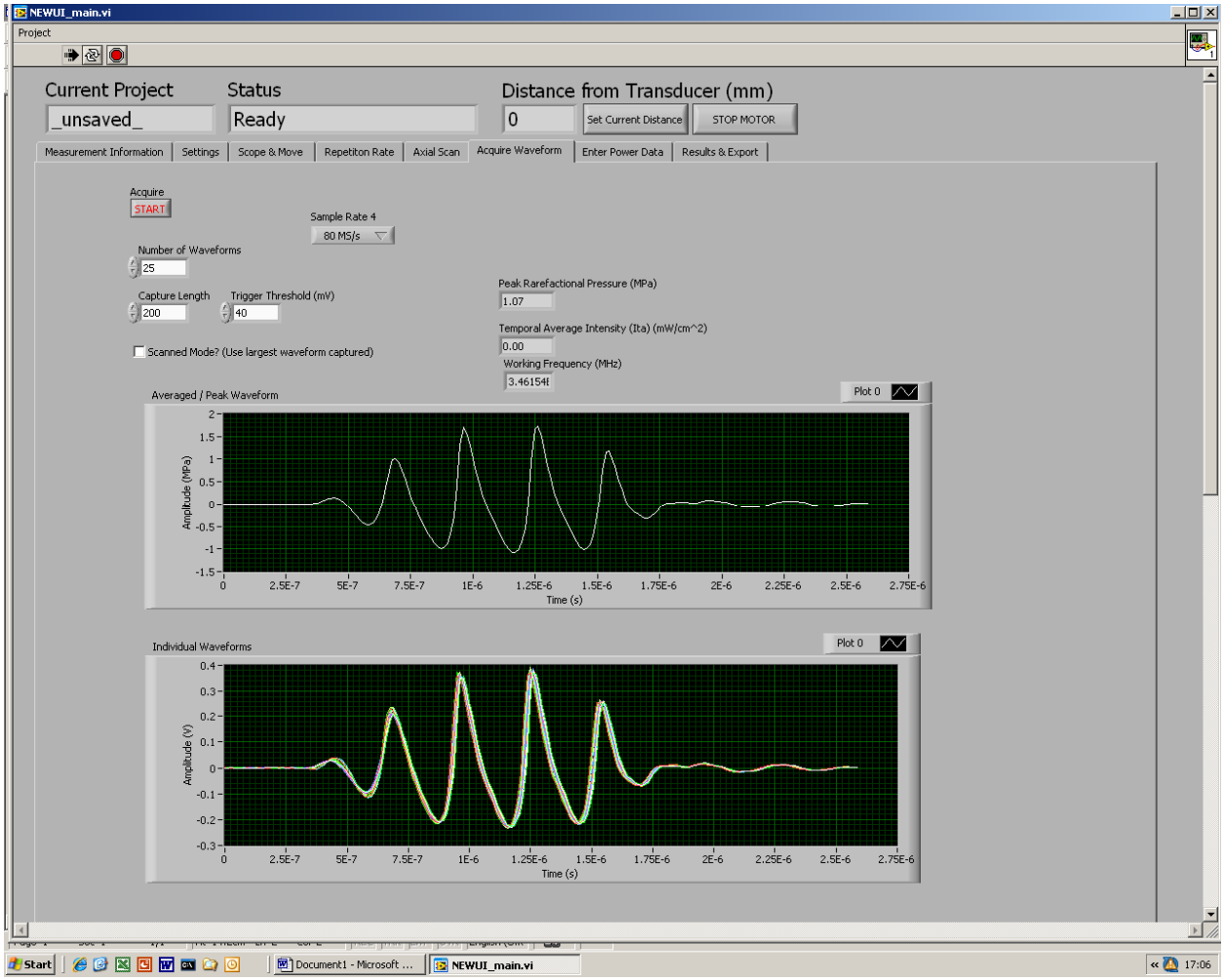
Alignment → PRR/FRR → Axial Scan → Frequency → Power → Calculations

Measurement Procedure (7/10): 3) Axial Scan



Alignment → PRR/FRR → Axial Scan → Frequency → Power → Calculations

Measurement Procedure (8/10): 4) Frequency Measurement

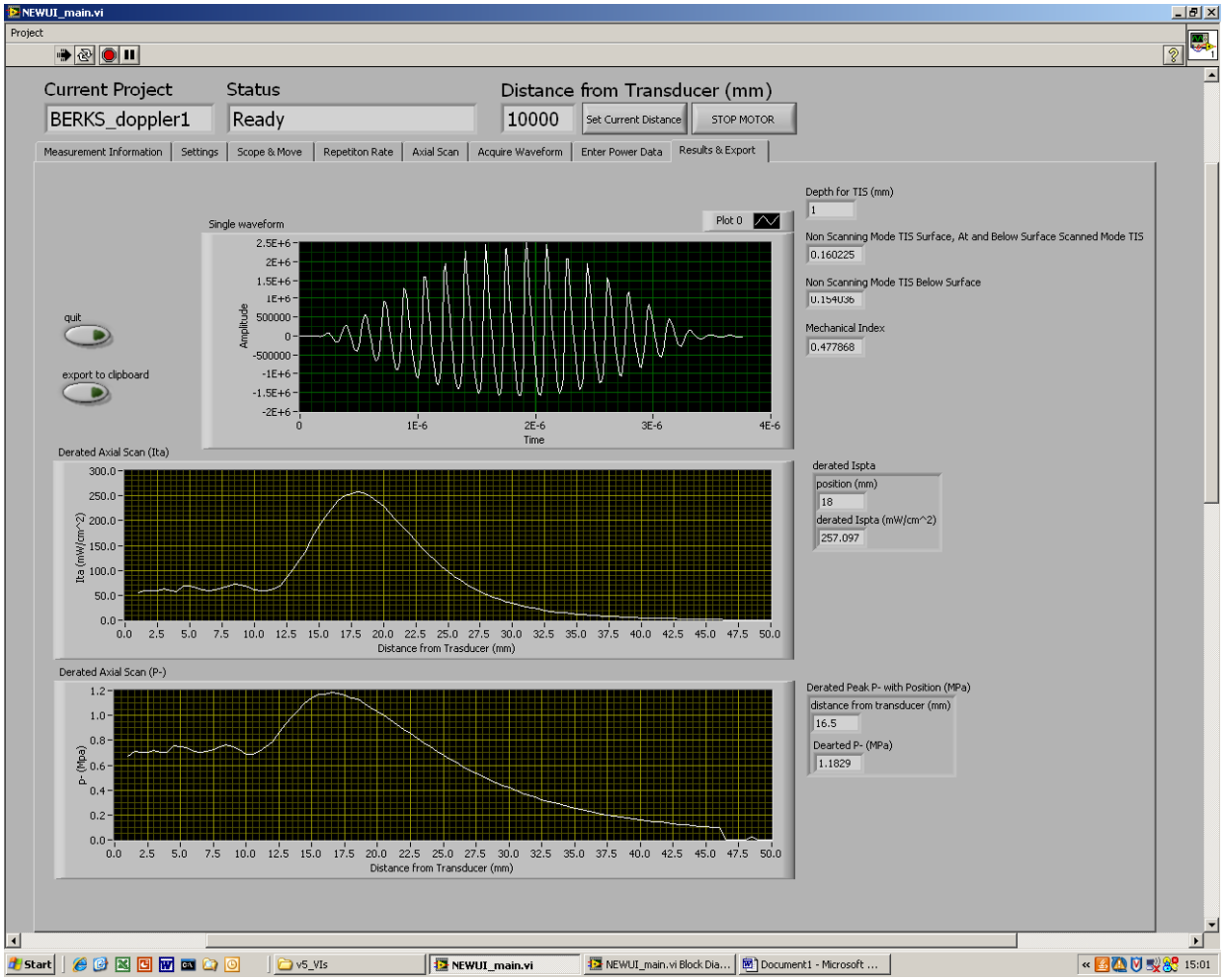


Alignment → PRR/FRR → Axial Scan → **Frequency** → Power → Calculations

Measurement Procedure (9/10):
5) Power Measurements

Alignment → PRR/FRR → Axial Scan → Frequency → **Power** → Calculations

Measurement Procedure (10/10):
6) De-rating and MI TI Calculation



Alignment → PRR/FRR → Axial Scan → Frequency → Power → Calculations

Testing

NPL
National Physical Laboratory

Barts and The London NHS
NHS Trust

Royal Berkshire NHS
NHS Foundation Trust

Royal United Hospital Bath NHS
NHS Trust

Summary

- Portable system
- Simple alignment of hydrophone to beam axis
- Automatic beam plotting
- Simple power measurement as part of same system
- Automatic calculation of MI and TI

Future Work

- Easier alignment
- Reduce effect of vibration on power sensor
- More portable
- Comparison with existing systems

Acknowledgments

Thanks to Bajram Zeqiri, Mark Hodnett, Adam Shaw, Jill Barrie, Andrzej Jastrzebski, Michael Lynn, Hazel Starritt and the National Measurement Office.

christian.baker@npl.co.uk

National Measurement System

The National Measurement System delivers world-class measurement science & technology through these organisations

NPL
National Physical Laboratory

National Measurement System

The National Measurement System delivers world-class measurement science & technology through these organisations

National Measurement Office

NPL National Physical Laboratory

LGC

nel technology for life