

# EMAT with Pulsed electromagnet for high temperature

*Francisco Hernandez-Valle*  
*Steve Essex & Steve Dixon*  
*Ultrasonics Group*

BINDT, September 2009

THE UNIVERSITY OF  
WARWICK

# OVERVIEW OF TALK

- |   |                         |   |                          |
|---|-------------------------|---|--------------------------|
| 1 | <i>Background</i>       | 4 | <i>Experimental work</i> |
| 2 | <i>High temperature</i> | 5 | <i>Conclusions</i>       |
| 3 | <i>EMATs</i>            | 6 | <i>Future work</i>       |

## *HIGH TEMPERATURE ULTRASONIC TRANSDUCTION*

*Design* → *Innovative  
Low cost  
Robust* → *Tackle high  
temperature inspection  
problems*

*Perform* → *Material property  
Defect detection* → *Mechanisms  
by which  
components  
degrade*



*Most commercial transducers are limited typically to applications that require operation temperatures below 200 °C*

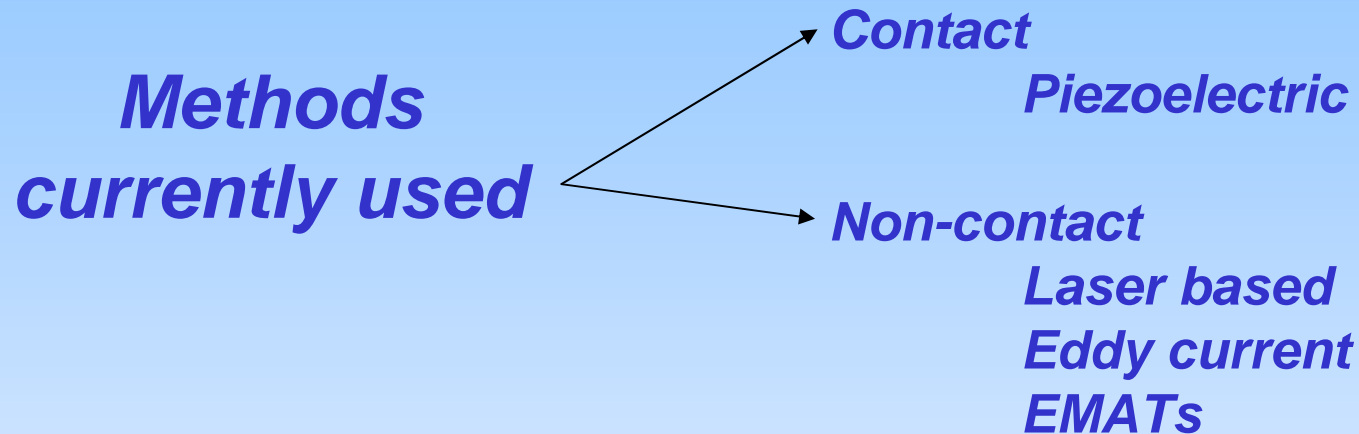
*Applications for higher temperatures*

- *Power industries*
- *Manufacturing processes*
- *Materials research*
- *Automotive sector*

***Benefits for developing transducers for these applications:***

- ◆ *Reduce operating costs by avoiding outages.*
- ◆ *Perform in situ monitoring.*

*Ultrasonic methods are well known and effective for NDT in both academic research and industry*

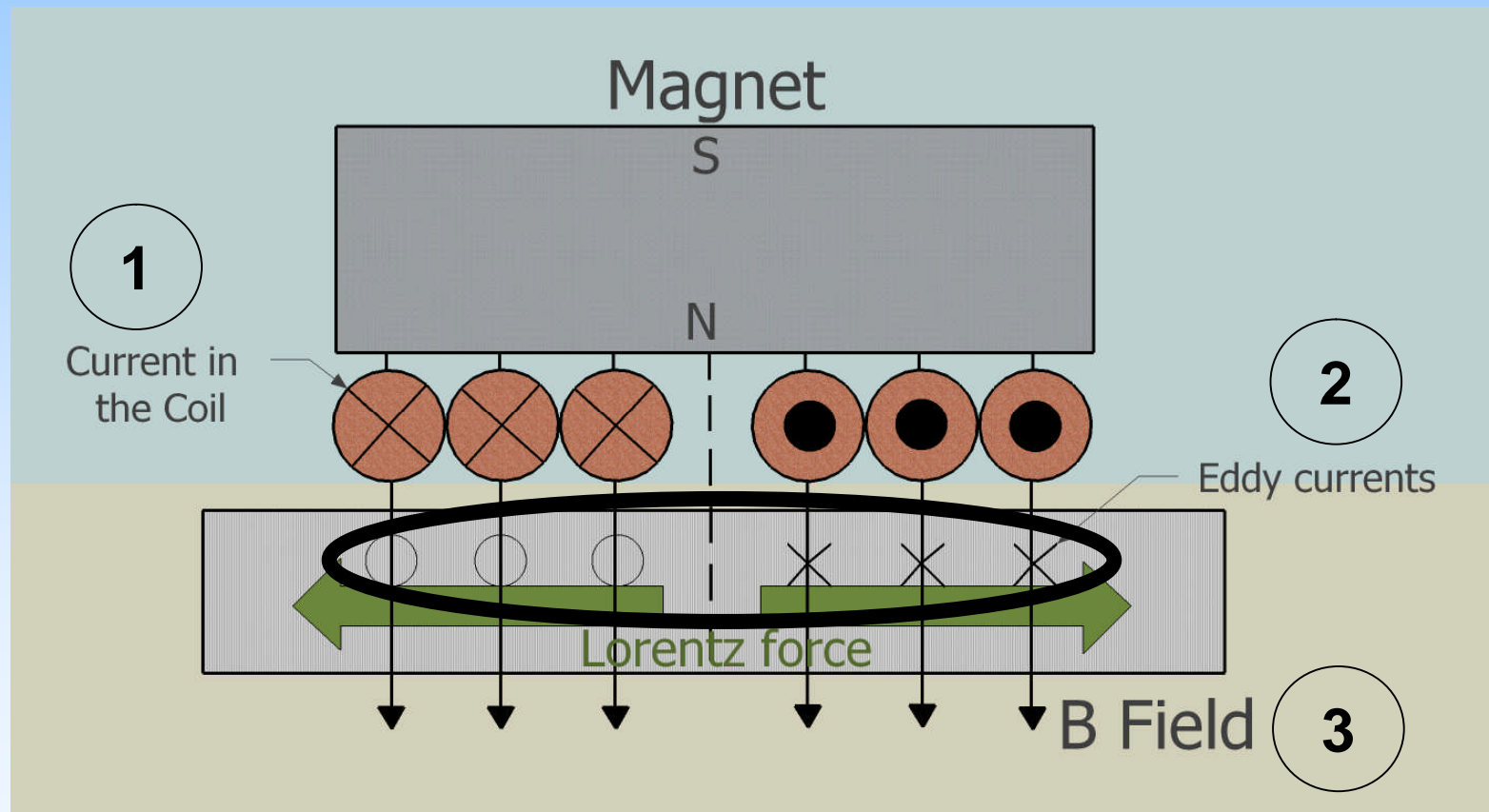


**Why using EMATs?**

- ➡ **Compact size**
- ➡ **Fairly inexpensive**
- ➡ **Couplant free**
- ➡ **Versatile**
- ➡ **Tolerates hostile environments**

# ELECTROMAGNETIC ACOUSTIC TRANSDUCERS

*Basically an EMAT is*  $\left\{ \begin{array}{l} \text{magnet,} \\ \text{coil of wire} \end{array} \right.$



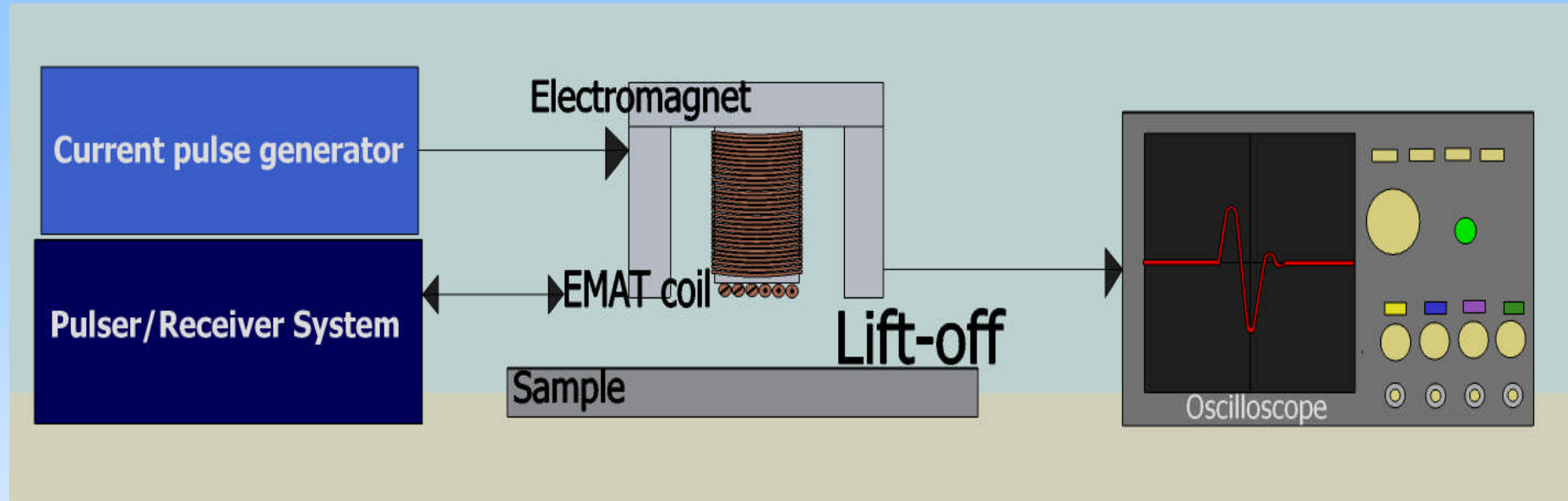
## *Permanent magnet*

***Vs***

## *Electromagnet*

- *Compact size*
- *High magnetic field provided*
- *Low Temperature Operation  
(100-150 °C in NdFeB)*
- *Cooling required*

- *Reasonable size*
- *High magnetic field provided*
- *Suitable for high temperature*
- *Reduces average power required (compact & less complex power supply).*

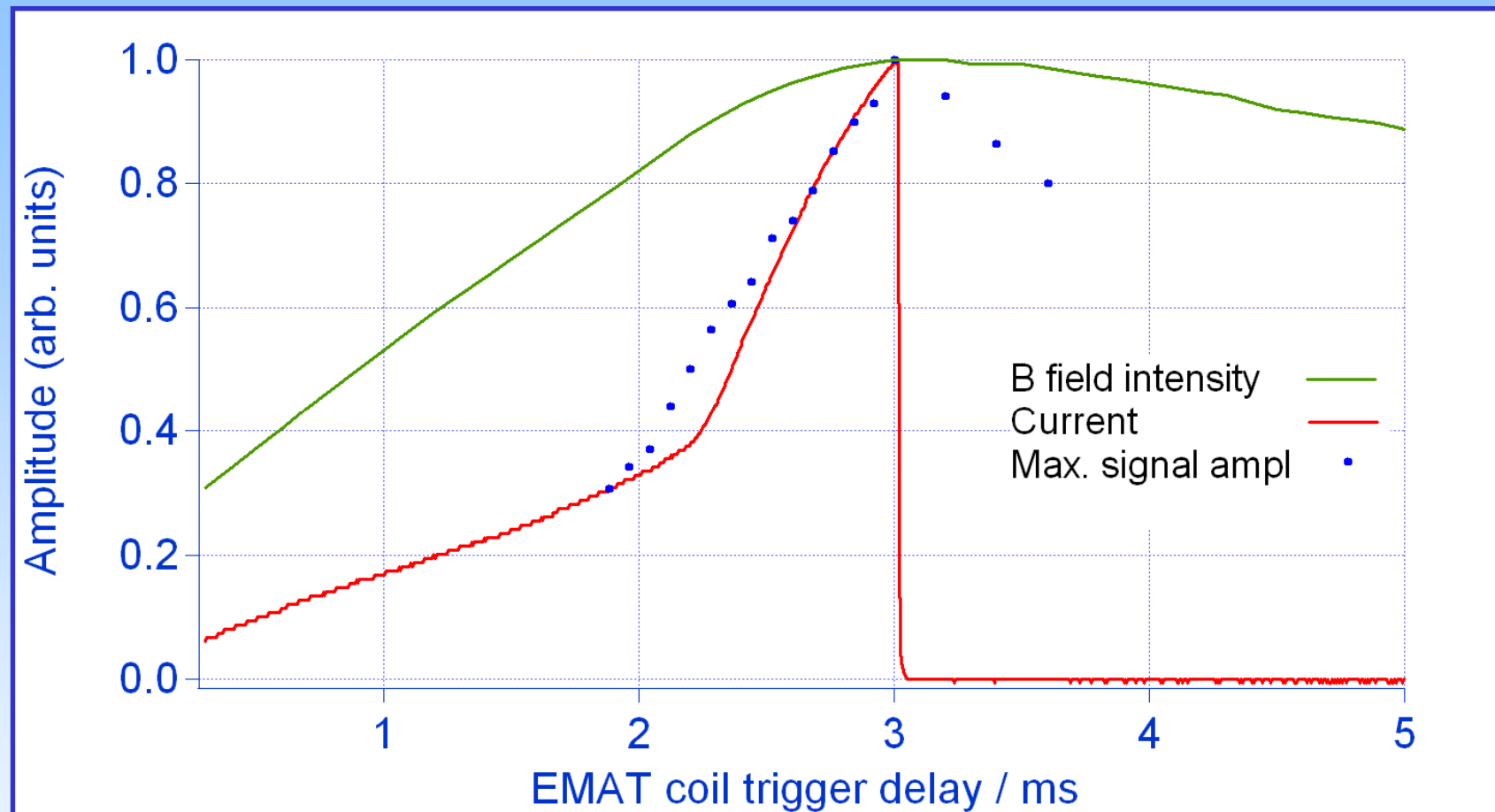


- (i) Optimizing EMAT
- (ii) On the surface
- (iii) Magnetic field

- (iv) Lift-Off performance
- (v) HT Performance



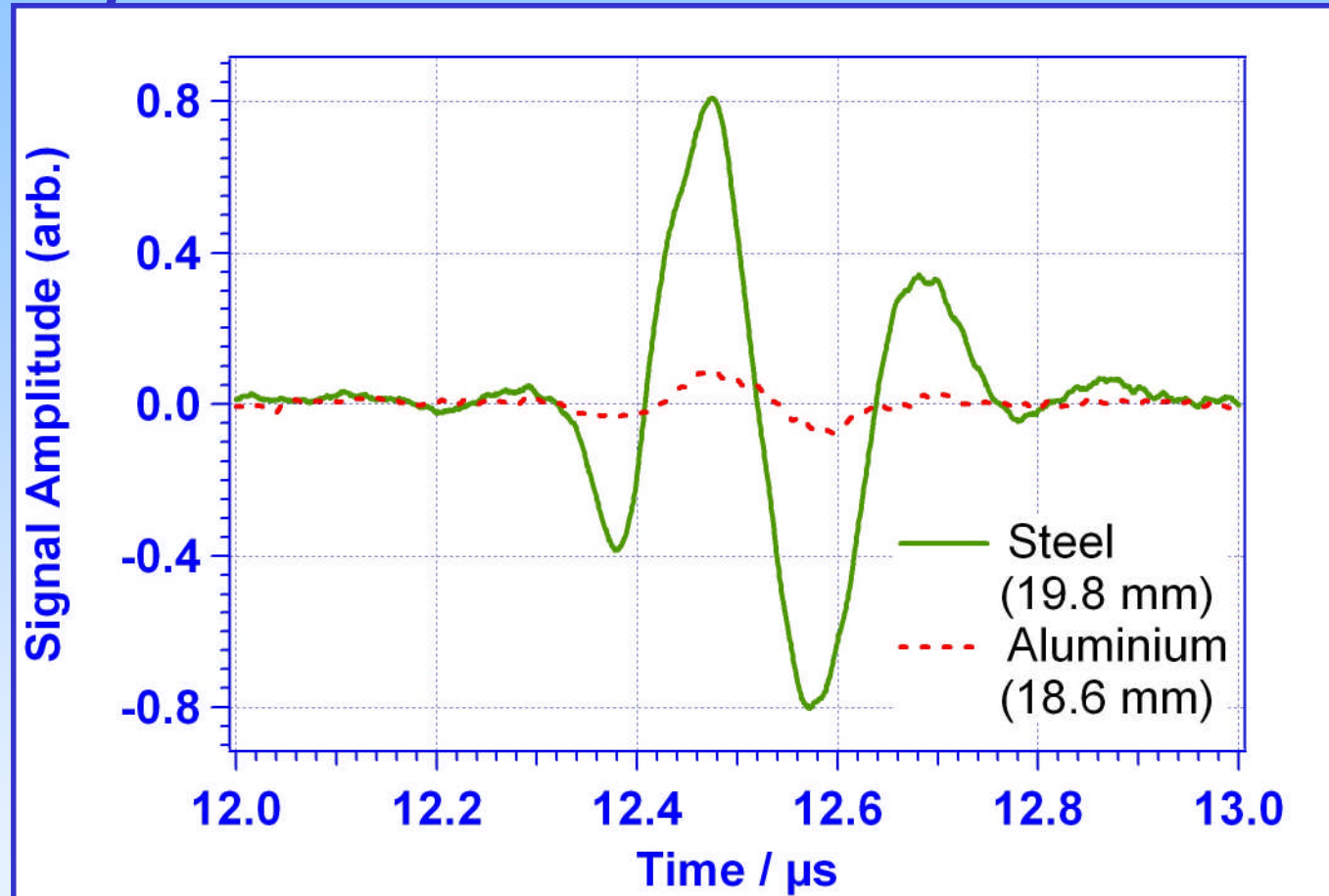
# OPTIMIZING SEND/RECEIVE EMAT



*Ultrasonic signal amplitude varied as a function of magnetic field intensity and current through the coil*

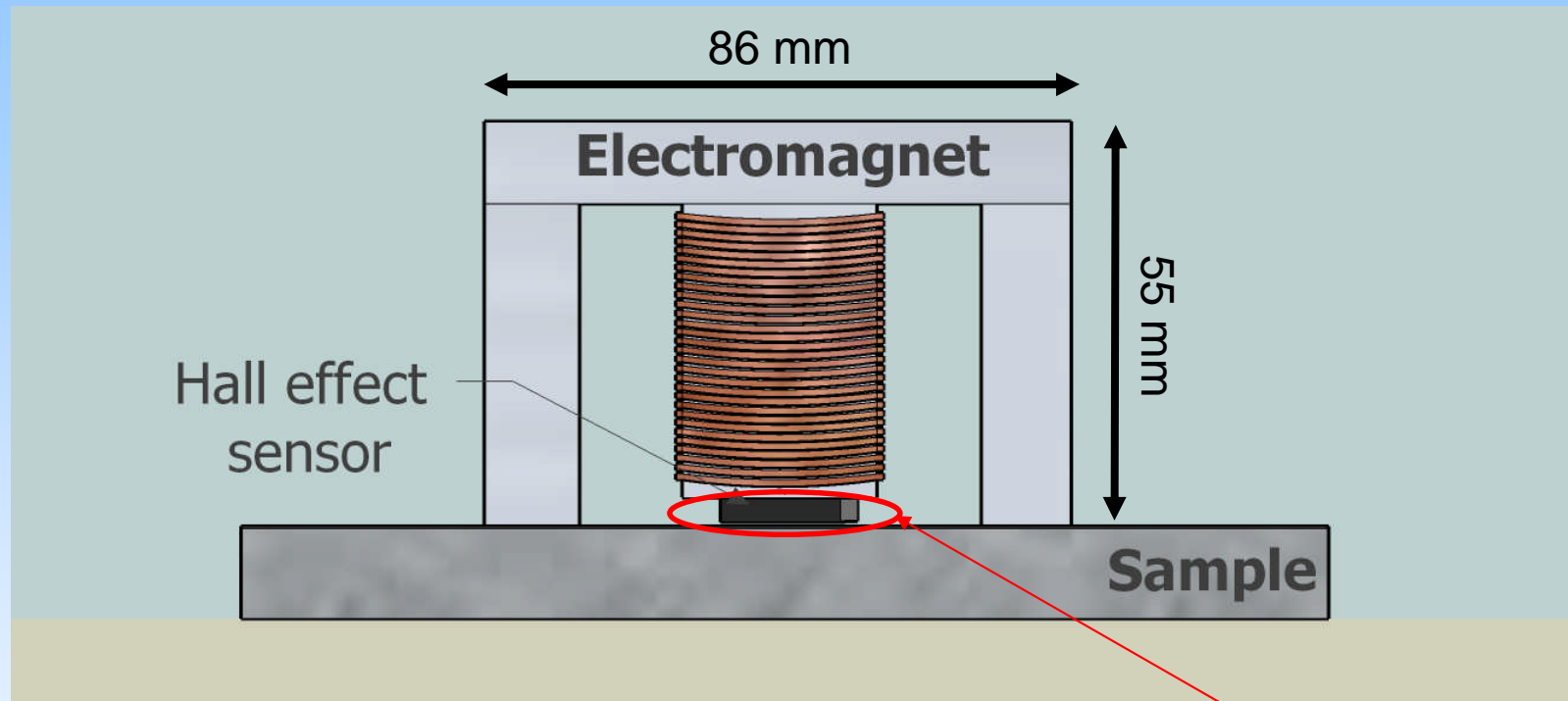
# ON-SURFACE PERFORMANCE

*Better performance on steel than on aluminium*



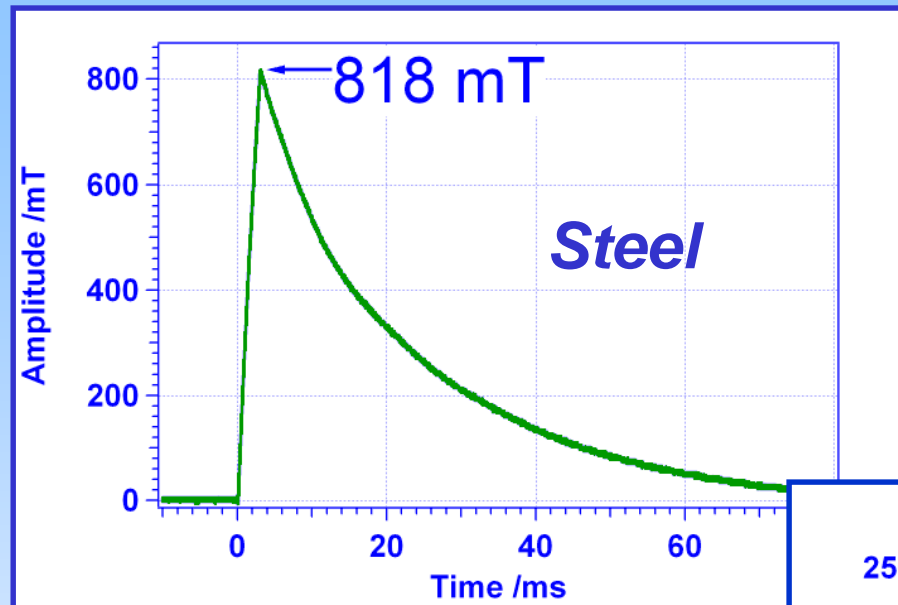
- ◆ *Shear wave in steel is significantly higher*
- ◆ *Shear wave in Al was time shifted for amplitude comparison*

## Set-up

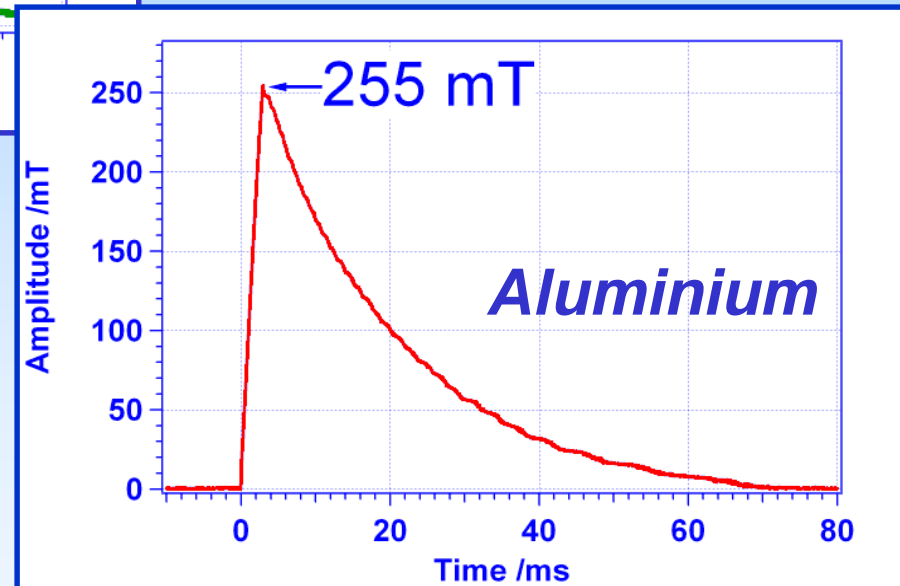


2mm gap designed to hold EMAT coil (removed for this measurement)

# MAGNETIC FIELD INTENSITY

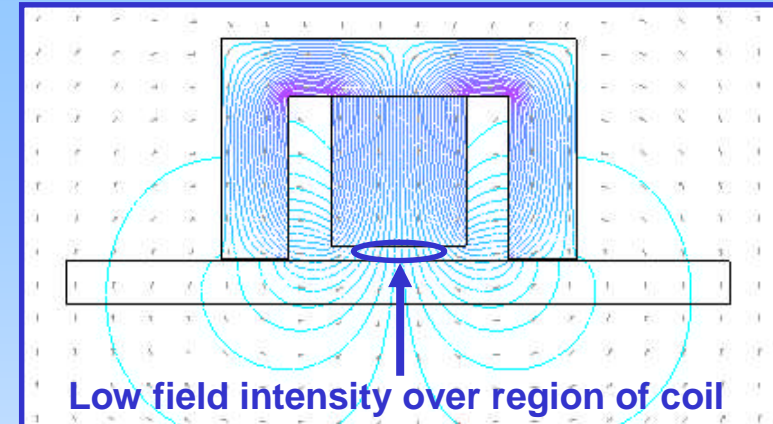
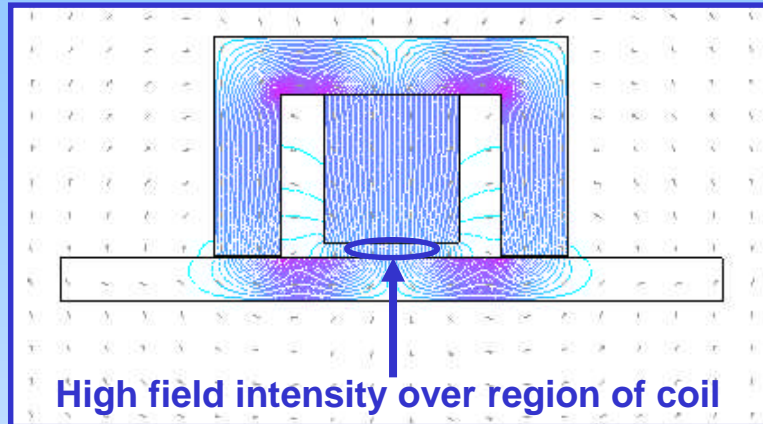


*Measured by the  
calibrated Hall  
effect sensor*

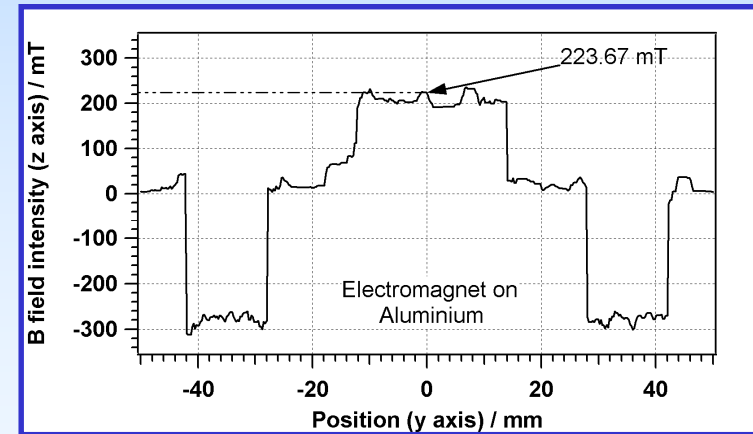
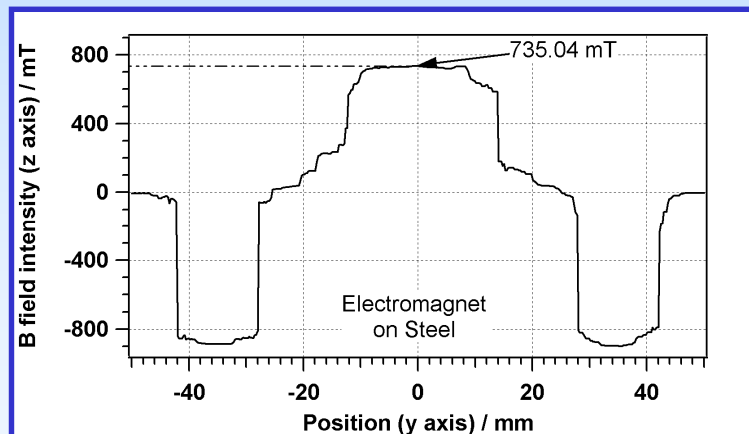


# MAGNETIC FIELD INTENSITY

## 2D FE simulation

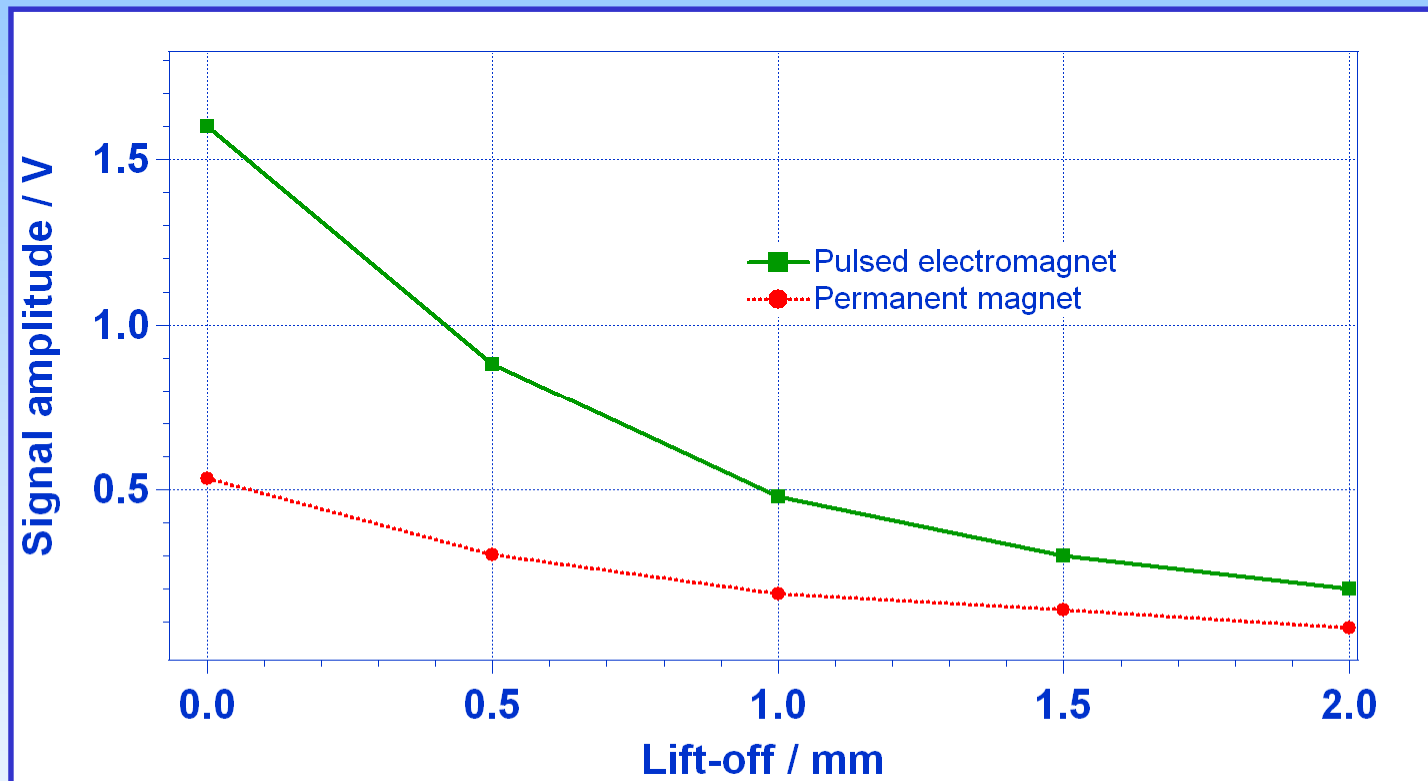


## 3D FE simulation



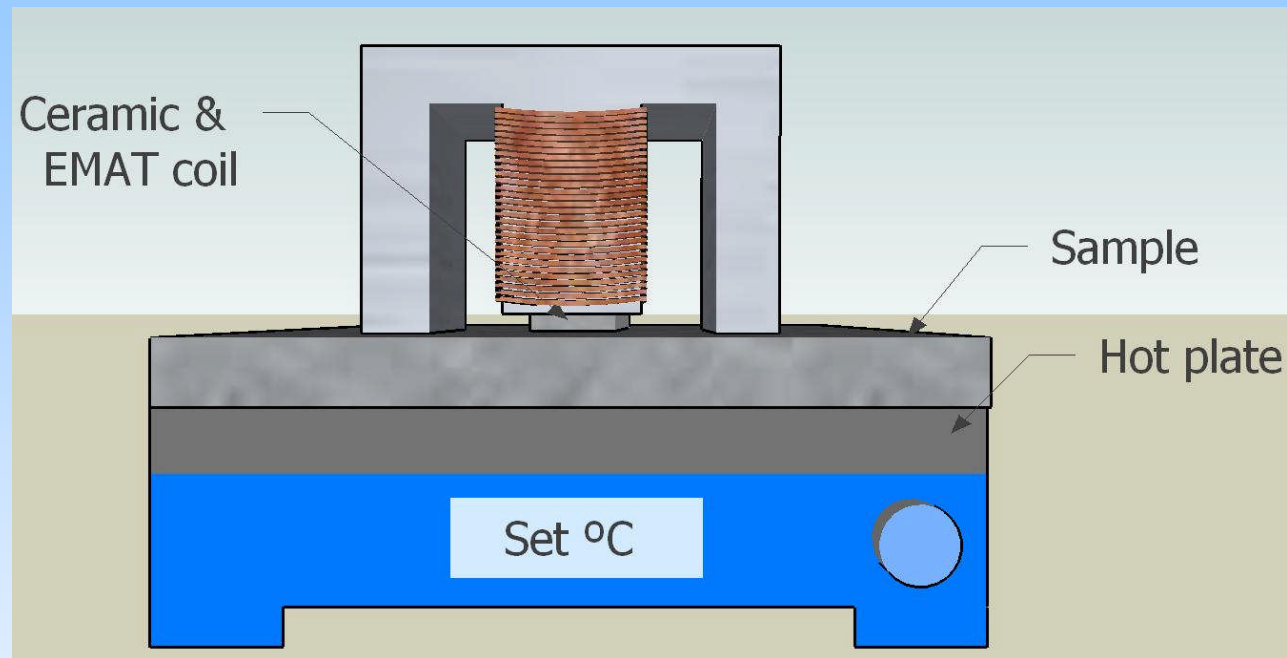
# LIFT-OFF PERFORMANCE

## *Pulsed electromagnet vs permanent magnet EMATs*



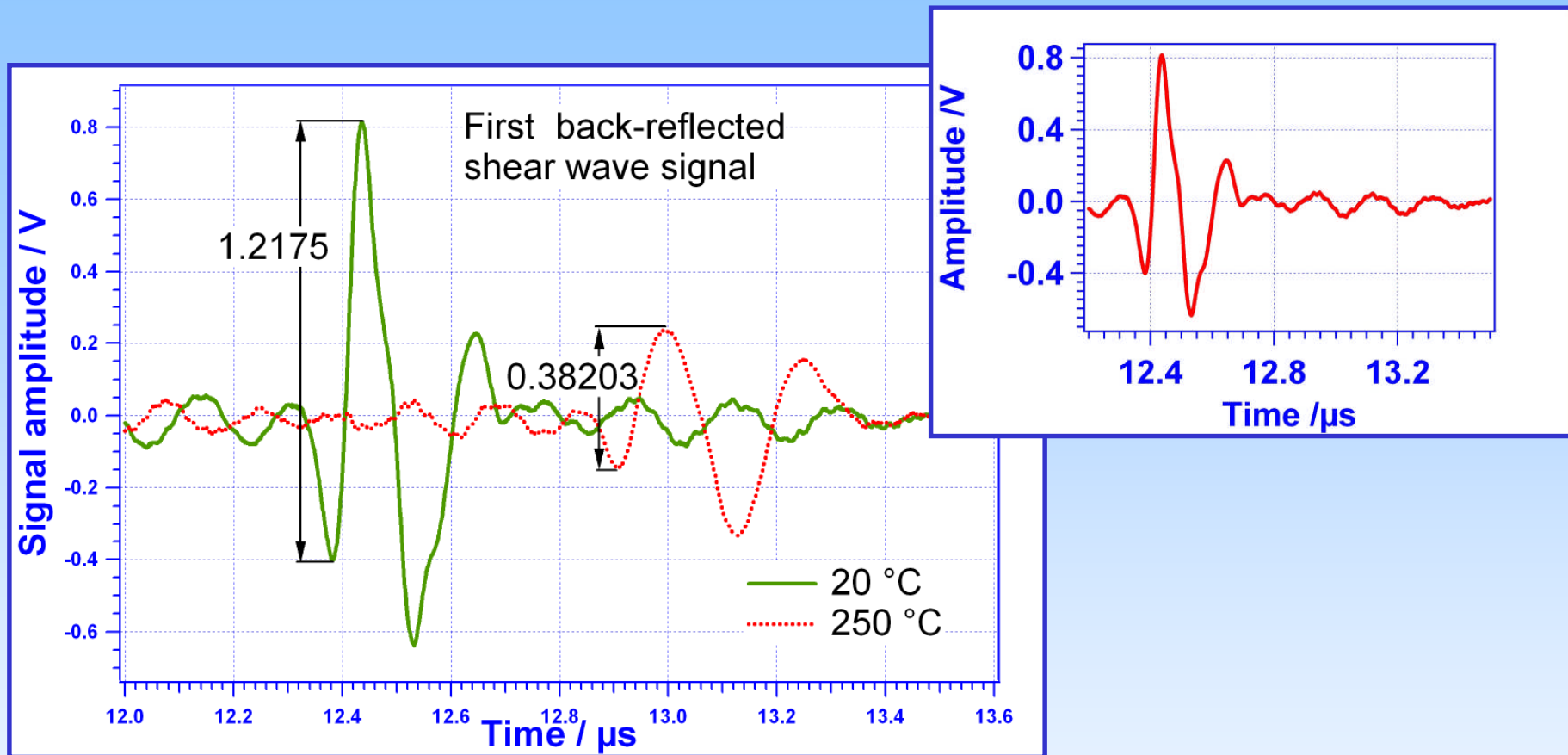
*The signal amplitude is enhanced approximately by a factor of three*

# SETUP FOR ELEVATED TEMPERATURES



***Surface sample temperature is monitored by a thermocouple.***

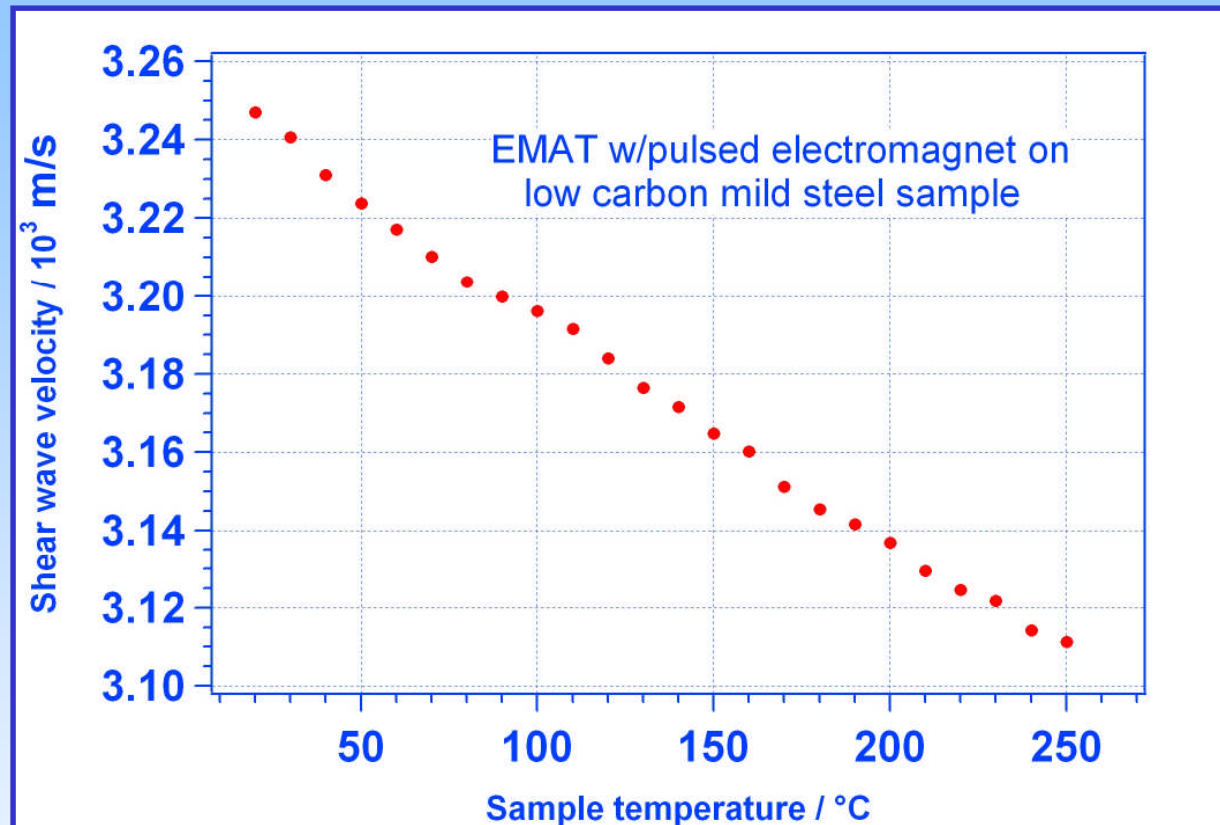
# RESULTS AT ELEVATED TEMPERATURES



*At HT, EMAT efficiency and shear wave velocity decrease.*



# RESULTS AT ELEVATED TEMPERATURES



*At HT, the shear wave velocity variation has to be taken into account*

- ➔ *It has been shown that is possible to perform measurements on low carbon mild steel with surface temperatures as high as 250 °C.*
- ➔ *Pulsed electromagnet EMAT outperforms permanent magnet on mild steel, but does not perform as well on aluminium at RT.*
- ➔ *Better lift-off performance than EMAT with permanent magnet.*
- ➔ *Valuable tool for many industrial applications at high temperatures.*

- ➔ *Improvement in the transducer design will be required to operate at temperatures significantly higher than 300 °C*
- ➔ *Model the generation and propagation of ultrasonic waves in the test components at high temperatures and comparing it with the experimental work.*
- ➔ *Measure materials' elastic properties at a range of temperatures as a detector alone / generator alone / combined generator and detector.*

<http://www.warwick.ac.uk/go/fhvalle>

## ePortfolio >> Research Student Directory

Home

Jose Francisco Hernandez-Valle

My Research  
My Teaching  
Curriculum Vitae  
Profile



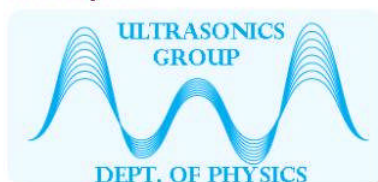
Signed in as:  
Jose Hernandez-Valle (phrhd)  
[Sign out](#)

Powered by [Sitebuilder](#)  
© MMTV | [Privacy](#)  
[Accessibility](#)

Jose Francisco Hernandez-Valle

## Welcome to my ePortfolio

Hi everyone!



My name is J. Francisco Hernandez Valle and I am a PhD student in the University of Warwick. My research interests lie in the area of ultrasonic transduction and I am particularly interested in develop a high temperature monitoring and inspection system using state of the art ultrasonic devices. My supervisor is [Dr. Steve Dixon](#), who is head of the Ultrasonics group in the Physics Department. Funding for my work is provided by [CONACyT](#) (Mexican Council on Science and Technology), the [Royal Academy of Engineering](#) and [Elster Group](#).

### About my research

There are many instances where components and plant operate at elevated temperatures such as within turbines, high temperature processing pipework, power generation boilers and reactors. Almost all inspections of such machinery are carried out at lower or ambient temperature, necessitating at least partially shutting down the plant or the process.

Ultrasonic methods are generally recognised as one of the most flexible and powerful methods for non-destructive testing in academic research and industrial environments. To date, there are a number of methods used for inspection of metallic components at high temperature, including eddy current and laser based ultrasonic methods. However, ultrasonic measurements are generally limited to temperatures below 200-300 °C because above this range there are in general no suitable commercially available ultrasonic transducers. Consequently, novel ultrasonic transducers, capable of operating at higher temperatures are of great interest to both academic researchers and potential industrial users.

If you want to find more about my current work please explore [My research...](#)

Please feel free to have a look around my eportfolio by clicking in one of the following links or using the navigation bar on the left:

[PROFILE](#)

[MY RESEARCH](#)

[MY TEACHING](#)

[CV](#)

**News:** I was awarded with a Student Development Fellowships 2008, funded by the Royal Academy of Engineering and Elster Group



Jose Francisco Hernandez Valle

[Contact Me](#)

[Ultrasonics Group](#)

[Department of Physics](#)

[University of Warwick](#)

Coventry

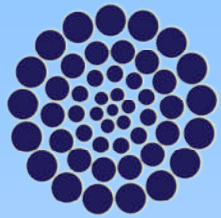
CV4 7AL

TEL: [+44 \(0\) 24765 23414](#)



[j.f.hernandez-valle@warwick.ac.uk](mailto:j.f.hernandez-valle@warwick.ac.uk)

# ACKNOWLEDGMENTS



**CONACYT**

*Consejo Nacional de Ciencia y Tecnología*



The Royal Academy  
of Engineering



**elster**

***Thank you for your attention***

***Any questions?***