



CCLRC

Rutherford Appleton Laboratory

# Pulsed Techniques and Sample Environments

James Lord  
ISIS

## Pulsed Techniques and Sample Environments

- Most muon experiments vary the temperature and magnetic field
  - We can also consider applying:
    - Electric fields
    - Currents through the sample
    - Light (ionisation, excitation)
    - Pressure
    - Gases (reactions/absorption)
    - Strain (static, sound waves)
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## Why pulsed?

- Science:
    - Direct effect of time-varying environment (eg. RF)
    - Observe slow formation of final muon states
    - Measure recovery time of sample after a pulse (eg. charge carrier recombination), or non-equilibrium state of the sample
  - Practical:
    - At ISIS, muons are only in the sample for 0.1% of the time!
    - Higher intensity available (eg. lasers or flash lamps)
    - Avoid sample heating (eg. light, pulsed currents)
    - Avoid other problems with steady state conditions (eg. charge accumulation due to electric field)
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## Practical points

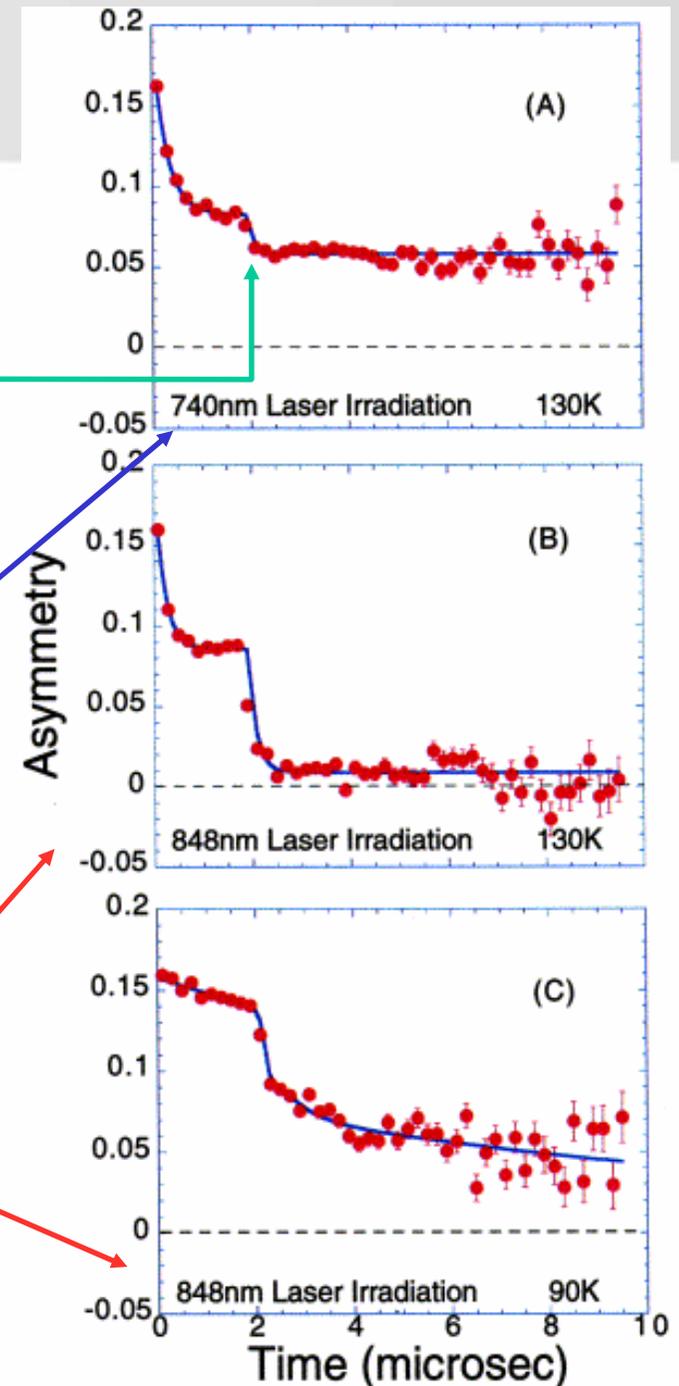
- The stimulus must be pulsed at the same frequency as the beam: 50Hz at ISIS, or a sub-multiple such as 10Hz.
- Time the pulse to:
  - Before the muons allowing the sample to relax for time  $t$
  - Coincident or just after the muon arrival, to interact directly with the muon
  - After the muons have decayed, as a check on sample heating
- Usually measure in “red-green” mode, 2 sets of histograms
  - Red: stimulus applied
  - Green: control measurement without pulse

## Illumination

In this example a laser pulse is applied at  $t=2\mu\text{s}$   
(GaAs, Shimomura et al)

Photons with energy above the band gap generate electron-hole pairs, which may interact with the muon, changing its charge state and causing relaxation.

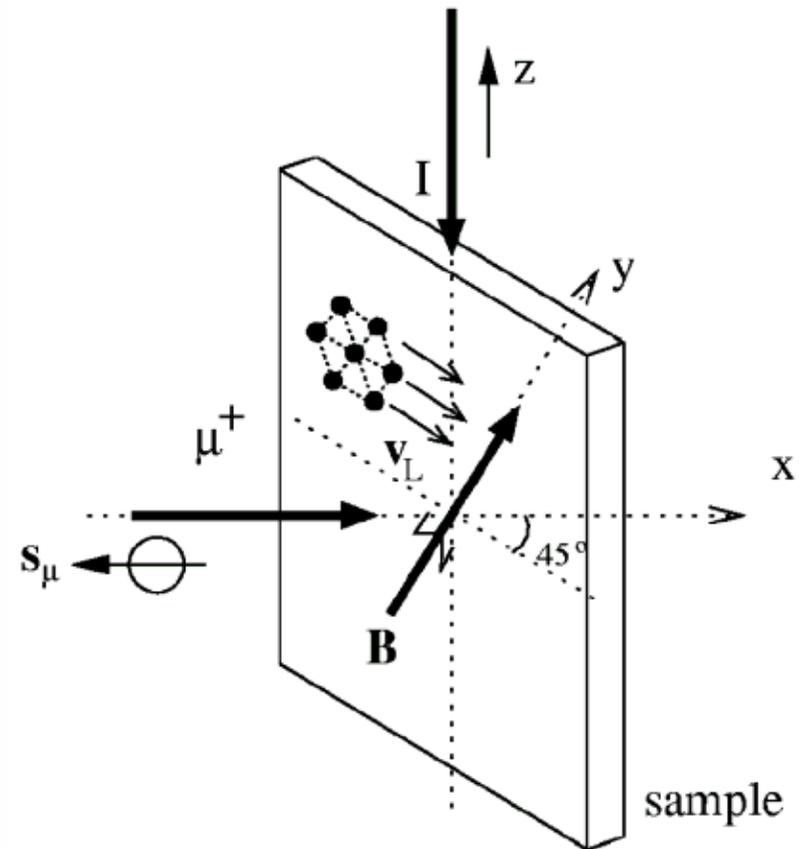
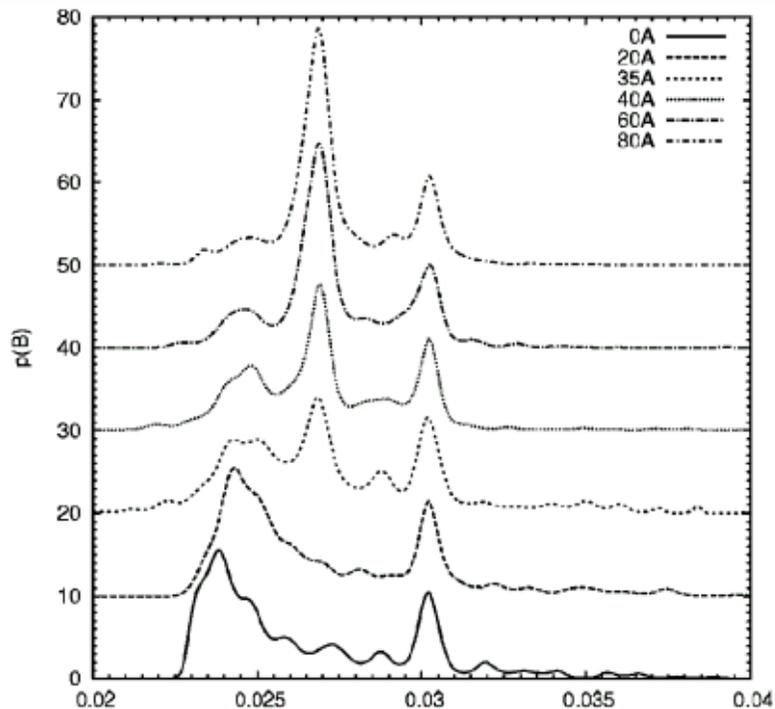
Below the band gap, the photons may directly ionise some muonium centres



# Current

Current flow in a type II superconductor is often accompanied by flux line motion. This “averages” the usual field distribution for a flux line lattice

Pulsed to allow higher currents without excessive sample heating

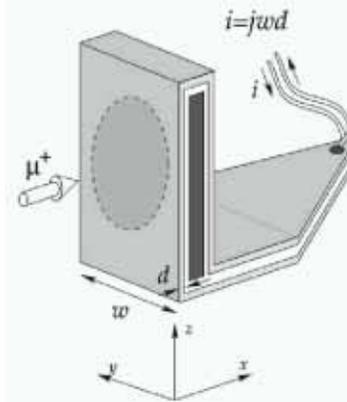


Internal field distribution (Maximum Entropy) for various currents (Pb-In sample, Charalambous et al)

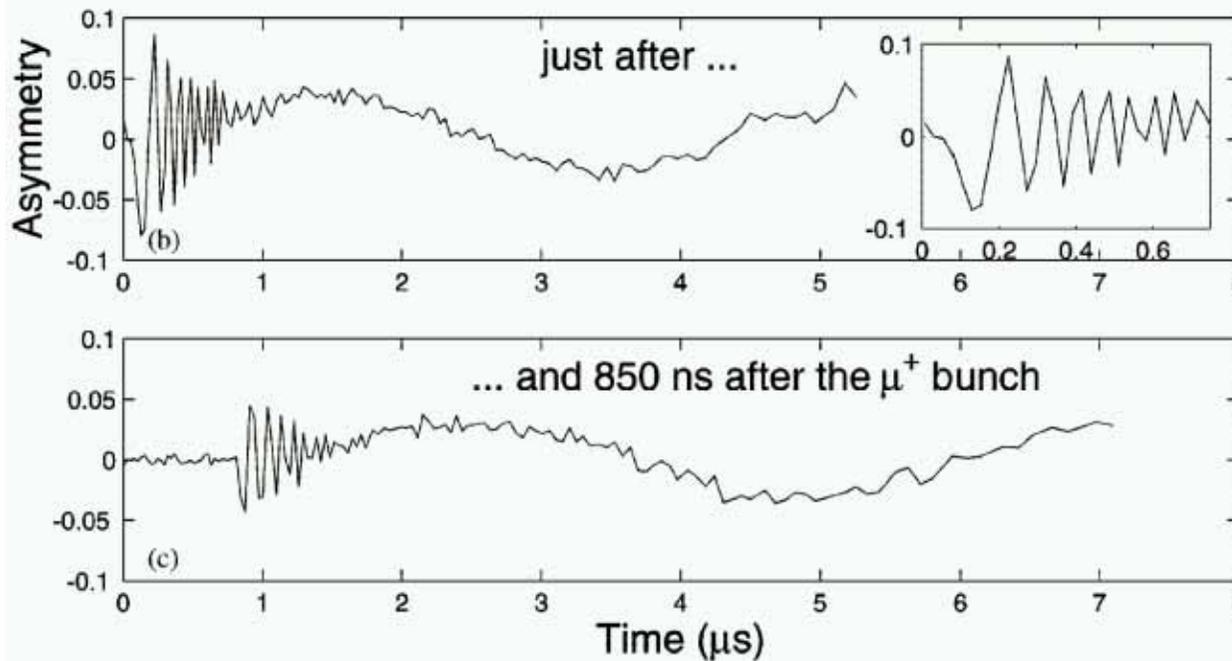
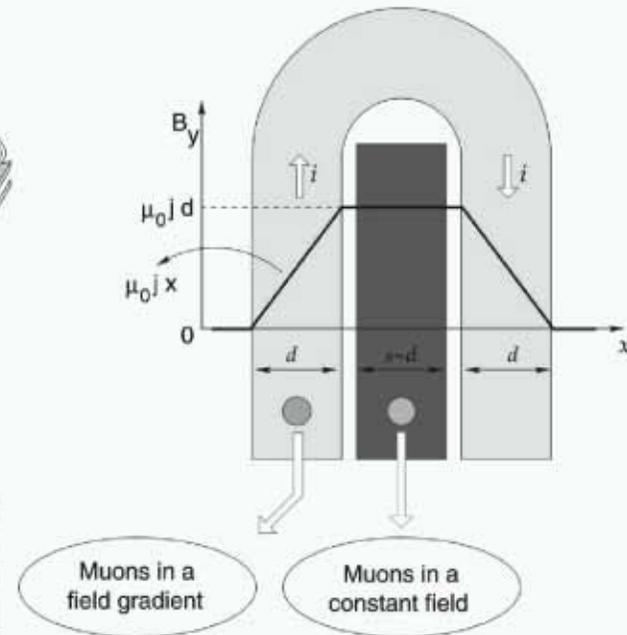
# Pulsed transverse fields

Muons initially implanted in a small longitudinal field, then the pulsed transverse field is turned on rapidly compared to the precession frequency.

Pulsed Magnetic Field Device



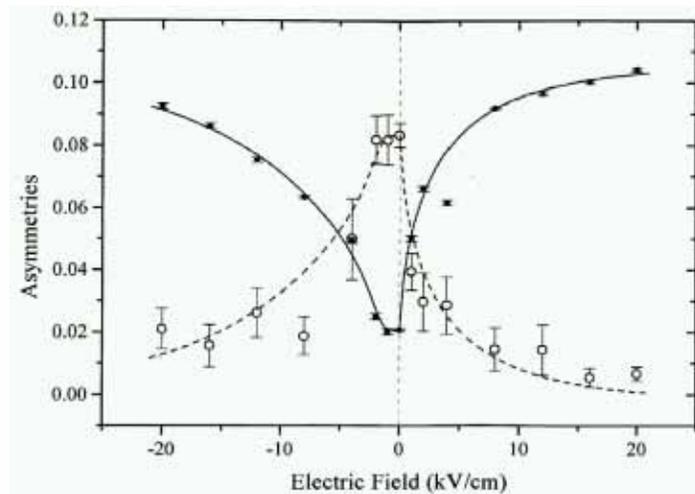
Section of the device



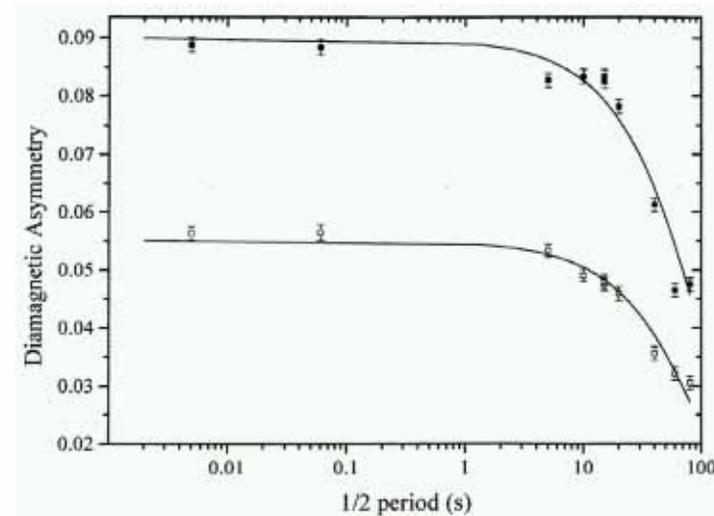
This technique removes the restriction of the muon pulse width and allows study of final states

## Electric fields

Electrons are produced as the muon stops in the sample. They may be swept away from the muon by the E-field, reducing muonium formation.  
Sample: GaAs,  $T=50\text{K}$  (Eshchenko et al)



Muonium (open) and diamagnetic fractions (filled circles) as a function of electric field



Variation of the diamagnetic fraction with switching rate due to charge build-up. ( $\pm 8\text{kV/cm}$  applied at electrodes)

## Pressure

- Muons can only penetrate a limited thickness of material (cell window)
- Thick windows are needed on a high pressure sample cell
- For “Surface” muons we can build cells up to 50 bar, eg. for gas experiments
  - Collision and reaction rates are pressure-dependent
  - Stopping range of muons in the gas depends on pressure



- “Decay” muons can penetrate cells up to a few kbar
  - Pressure dependence of solids eg. magnetic moments