

Mössbauer Spectroscopy

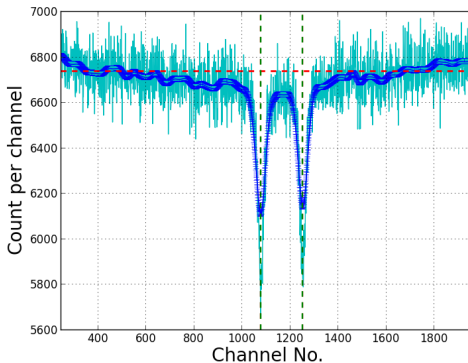
Yichao Yu

MIT

March 6, 2013

Mössbauer effect and Mössbauer spectroscopy.

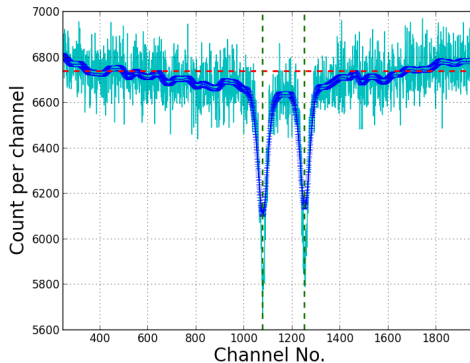
- Nuclear γ spectrum.
- Simple setup.
- Super high resolution. (10^{12})



Mössbauer spectrum of FeC_2O_4 .

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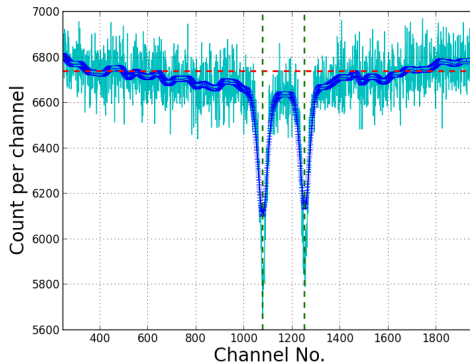
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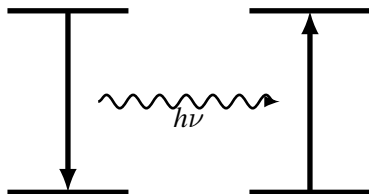
- 1 **Mössbauer effect.**
- 2 **Apparatus and samples.**
- 3 **Data and result.**
- 4 **Conclusion.**

Nuclear spectrum and recoil.

- Radio active element radiate γ -ray at characteristic frequencies.
- Radiation \rightarrow Absorption.
- Recoil momentum and doppler shift.

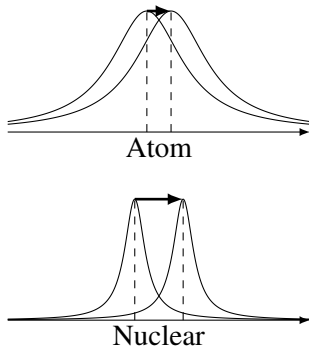
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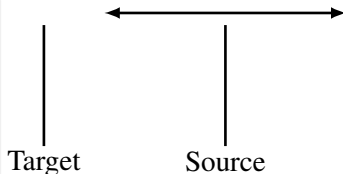
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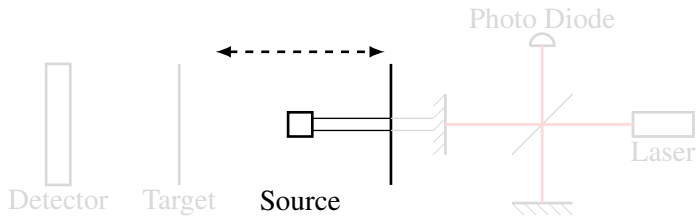
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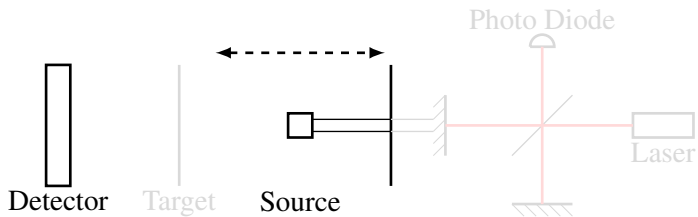
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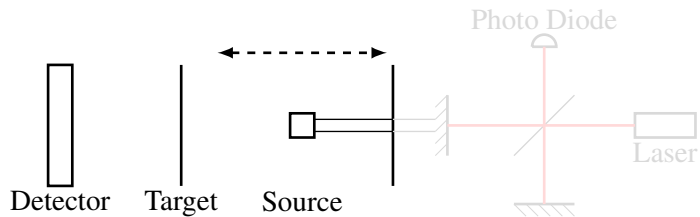
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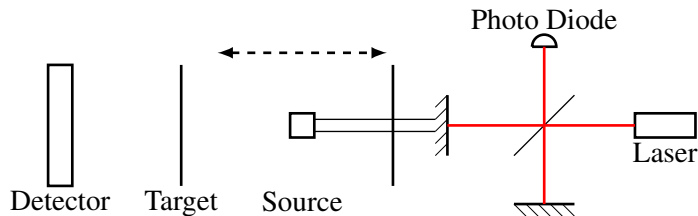
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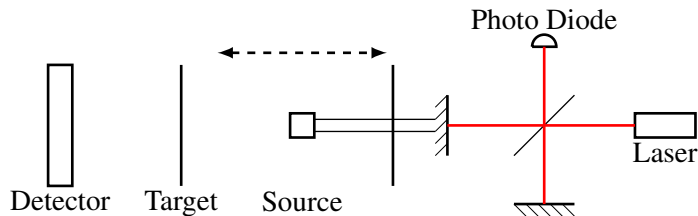


- Velocity of the source,

$$v = 2f\lambda$$

- Source: ^{57}Co .
- First decay into excited state of ^{57}Fe .
- Energy 14.4keV .

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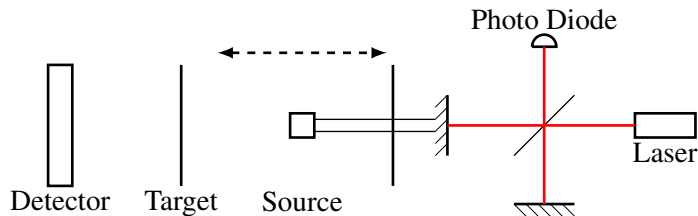


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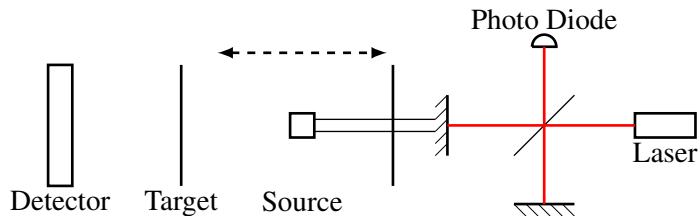


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Effects and samples.

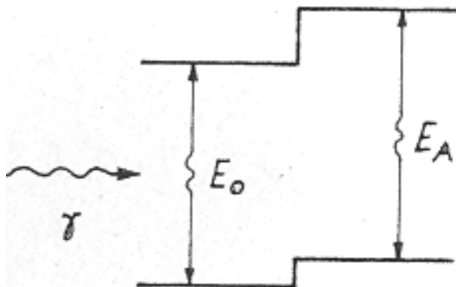
Effects

- Isomer Shift.
- Zeeman effect.

$$E = -g_N \mu_N B m_I$$

- Quadrupole Splitting.
- Temperature Shift.

$$\frac{\delta}{E} = \frac{v^2}{2c^2} = \frac{E_k}{mc^2}$$



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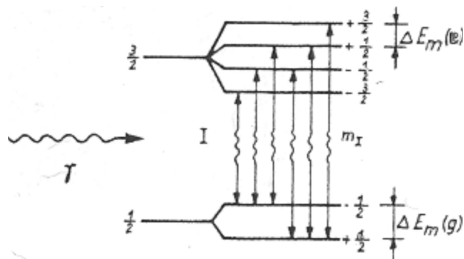
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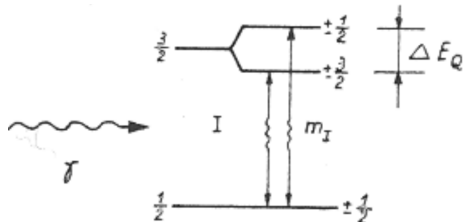
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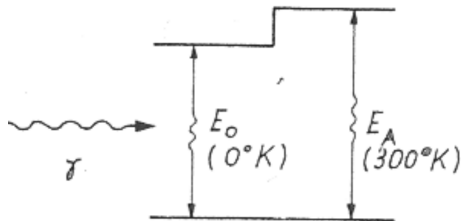
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Samples

- ^{57}Fe
- FeSO_4
- $\text{Fe}_2(\text{SO}_4)_3$
- Fe_2O_3
- Stainless steel (Varying temperature).
- $\text{Na}_4\text{Fe}(\text{CN})_6$ For line width.

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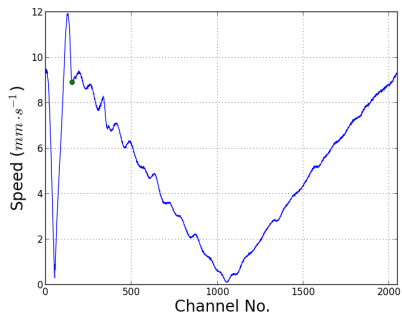
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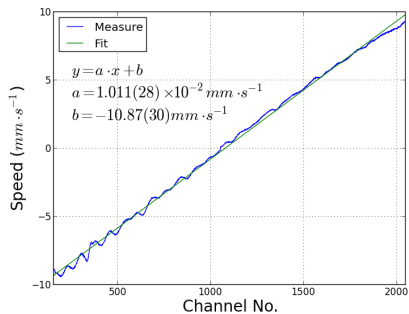
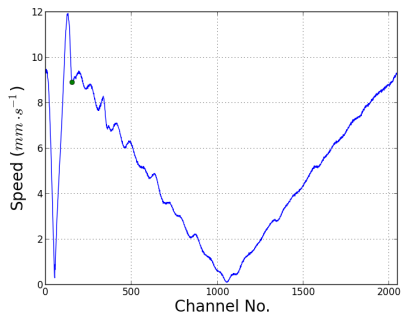
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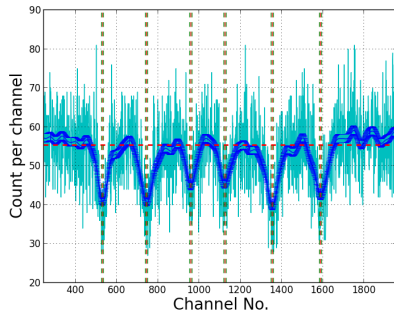
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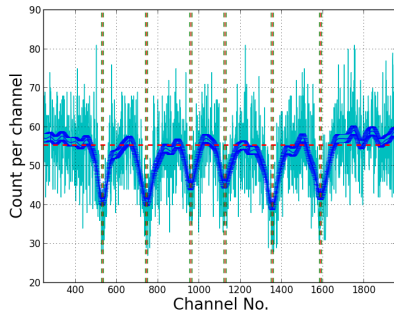
^{57}Fe and FeSO_4 .



Zeeman splitting for ground state (g_0) and excited state (g_1).

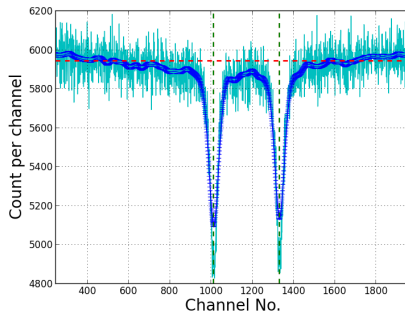
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Isomer shift (ϵ) and quadrupole splitting (δ).

ϵ	$5.9(1.4) \cdot 10^{-8} eV$
δ	$1.562(2) \cdot 10^{-7} eV$

Temperature effect.

Samples

- Classic:

$$E_k = \frac{3}{2}k_B T$$

- Debye T^3 approximation:

$$E_k = \frac{3\pi^4 * k_B * T^4}{10\Theta_D^3}$$

- Exact Debye Model:

$$E_k = \frac{9k_B T^4}{10\Theta_D^3} D_3 \left(\frac{T}{\Theta_D} \right)$$

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Model	E_k
Classic	$1.409(12) \cdot 10^{-2} eV$
Debye T^3	$4.59(22) \cdot 10^{-1} eV$
Exact Debye	$1.304(84) \cdot 10^{-2} eV$
(Measured)	$0.99(36) \cdot 10^{-2} eV$

Conclusion.

- Calibrated the velocity using laser.
- Measured Mössbauer spectrum of a variety of materials.
- Calculated different kinds of splitting and shifting.

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- Isomer Shift:

ε

- Zeeman effect:

g_0, g_1

- Quadrupole Splitting:

δ

$$\Delta E_1 = \varepsilon - \frac{g_0}{2} - \frac{3g_1}{2} - \frac{\delta}{2} \quad (1)$$

$$\Delta E_2 = \varepsilon - \frac{g_0}{2} - \frac{g_1}{2} + \frac{\delta}{2} \quad (2)$$

$$\Delta E_3 = \varepsilon - \frac{g_0}{2} + \frac{g_1}{2} + \frac{\delta}{2} \quad (3)$$

$$\Delta E_4 = \varepsilon + \frac{g_0}{2} - \frac{g_1}{2} + \frac{\delta}{2} \quad (4)$$

$$\Delta E_5 = \varepsilon + \frac{g_0}{2} + \frac{g_1}{2} + \frac{\delta}{2} \quad (5)$$

$$\Delta E_6 = \varepsilon + \frac{g_0}{2} + \frac{3g_1}{2} - \frac{\delta}{2} \quad (6)$$

