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Measuring magnetic fields with Cesium for the n2EDM experiment

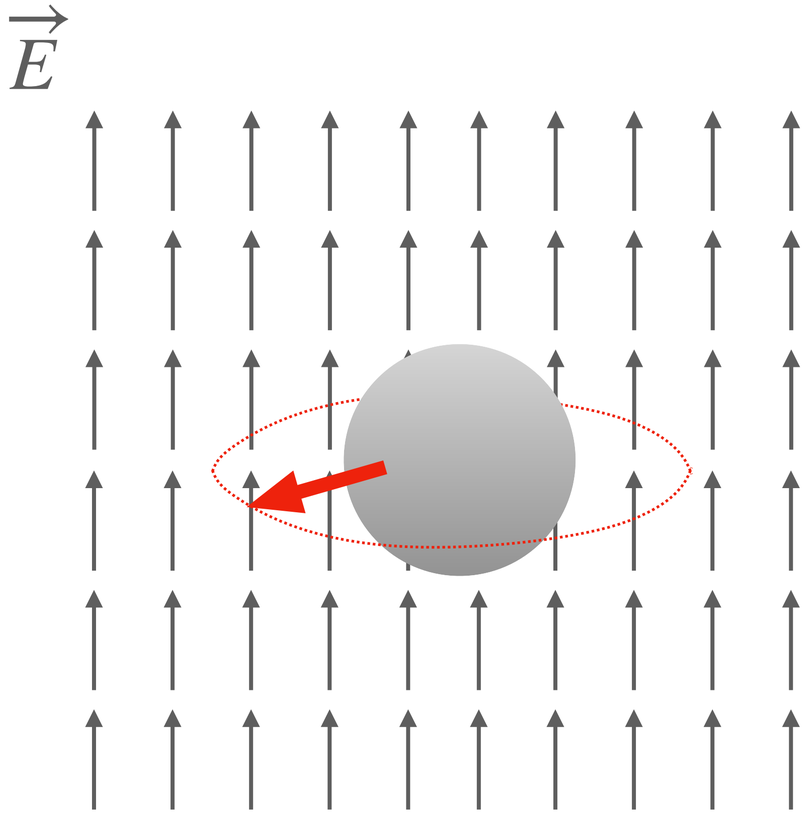
LTPHD Seminar

Lea Segner

Context: n2EDM experiment

- a non-zero neutron electric dipole moment d_n would cause the neutron spin to precess in an electric field $\vec{E}$ with frequency:

$$\hbar\,|\vec{\omega}\,| = 2d_nE$$



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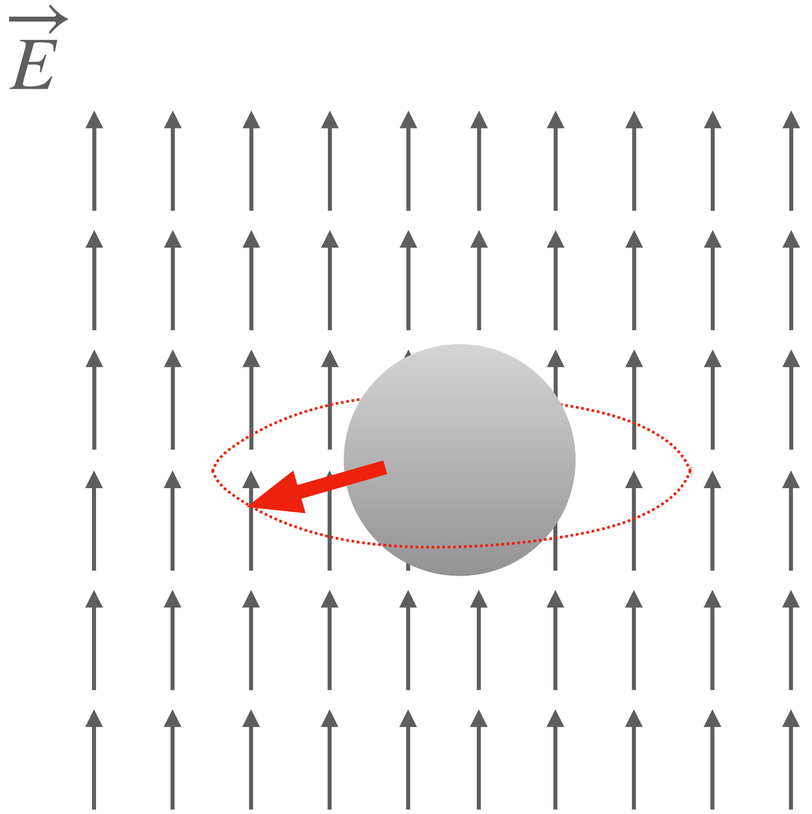
- The n2EDM experiment is built to measure the neutron precession frequency ω **BUT**

  $\omega \approx 7nHz$ **-> not realistically measurable** (1 precession = months or years)



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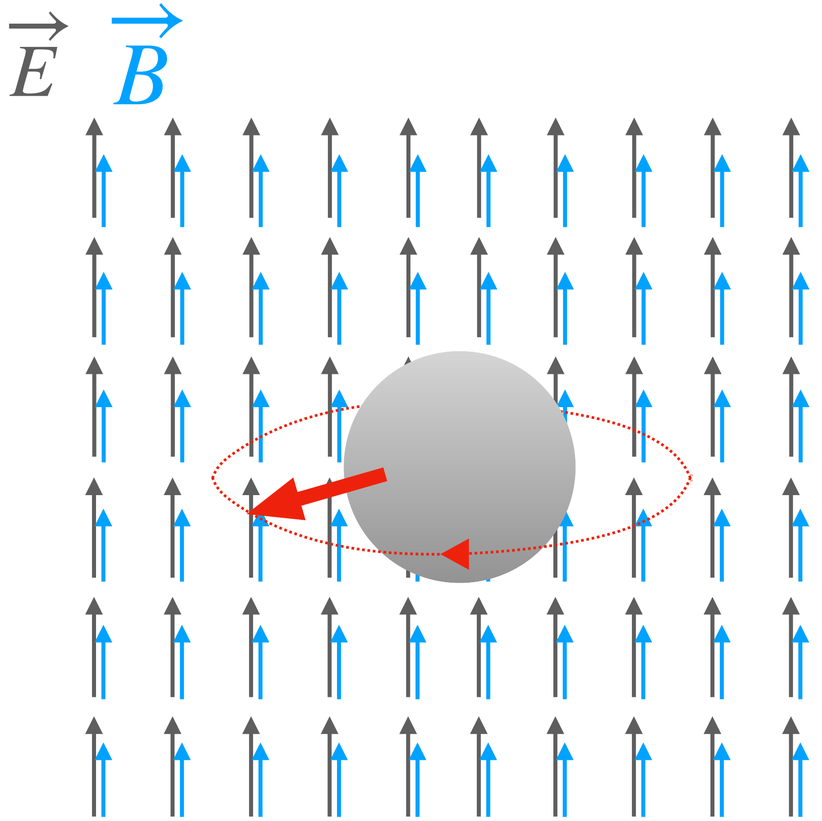
- Solution: Add magnetic field $\vec{B}$

$$\hbar\omega = g\mu_nB - 2\,d_nE$$



Context: n2EDM experiment

- Trick: Measure two configurations
- $\vec{B}$ and $\vec{E}$ parallel

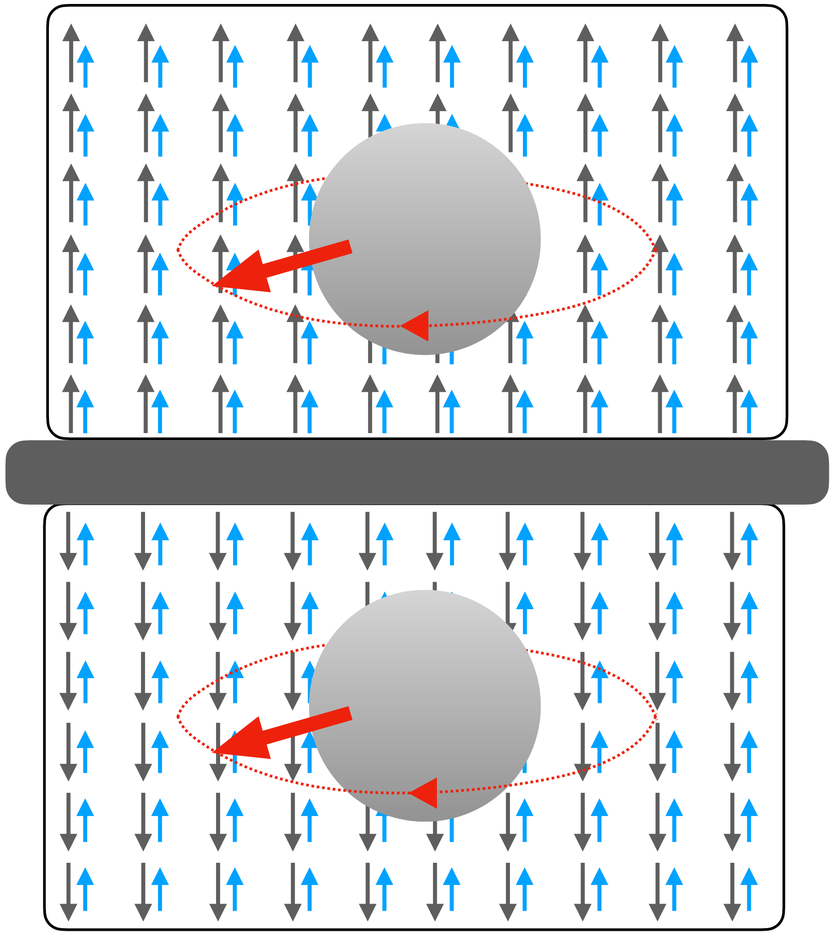
$$hf_{\uparrow\uparrow} = g\mu_n B - 2\, d_n E$$

- $\vec{B}$ and $\vec{E}$ antiparallel

$$hf_{\uparrow\downarrow} = g\mu_n B + 2\, d_n E$$

$$h(f_{\uparrow\uparrow} - f_{\uparrow\downarrow}) = -4 d_n E + g\mu_n(B - B)$$

$$d_n = \frac{h}{4E}(f_{\uparrow\downarrow} - f_{\uparrow\uparrow})$$



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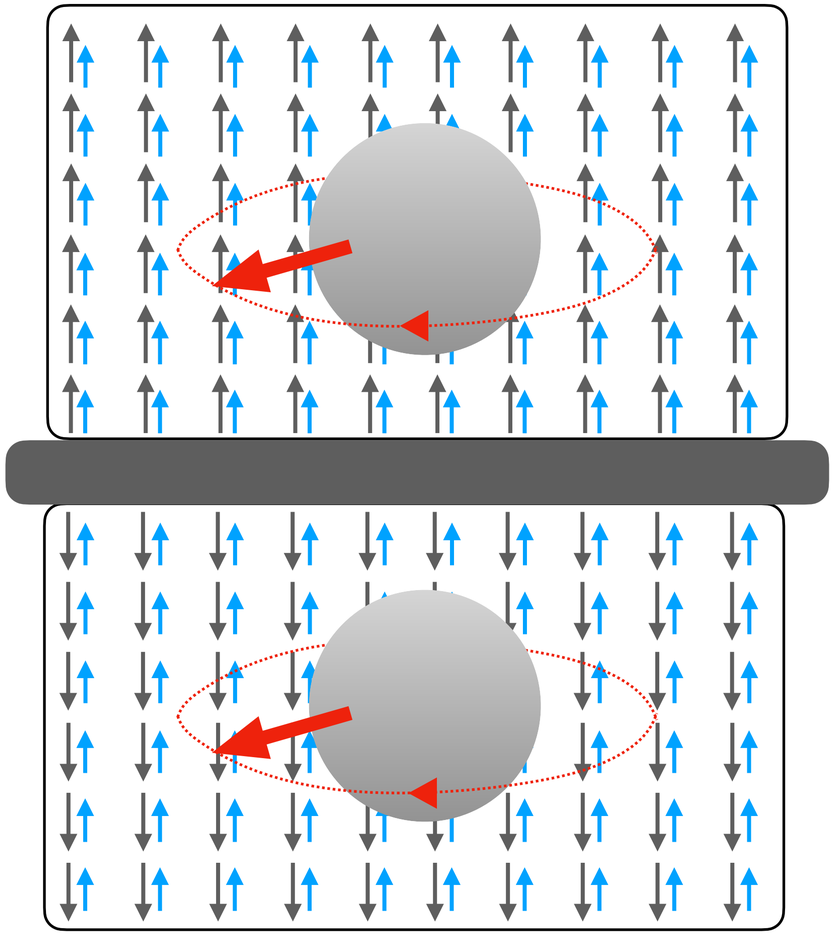

Quest for a well-controlled and well-characterised magnetic field

many team members!

Quest for a well-controlled and well-characterised magnetic field

Active magnetic shield (AMS)

first layer of protection from outside magnetic fields

Magnetically shielded room (MSR)

second layer of protection from outside magnetic fields

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Gradiometer

measures every part that goes in the experiment for magnetic contamination

Quest for a well-controlled and well-characterised magnetic field

Magnetic field mapper
offline mapping of the magnetic field

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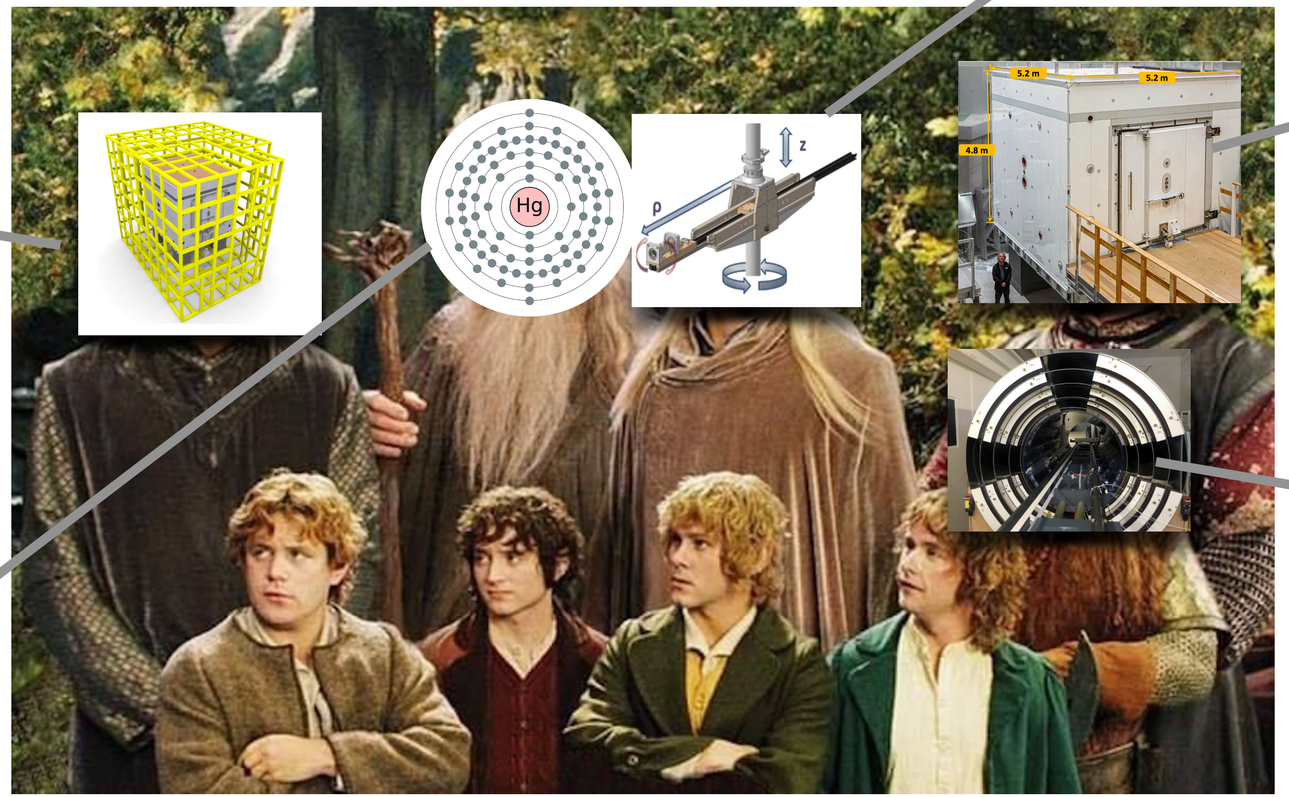

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Mercury magnetometer
online magnetic field measurements

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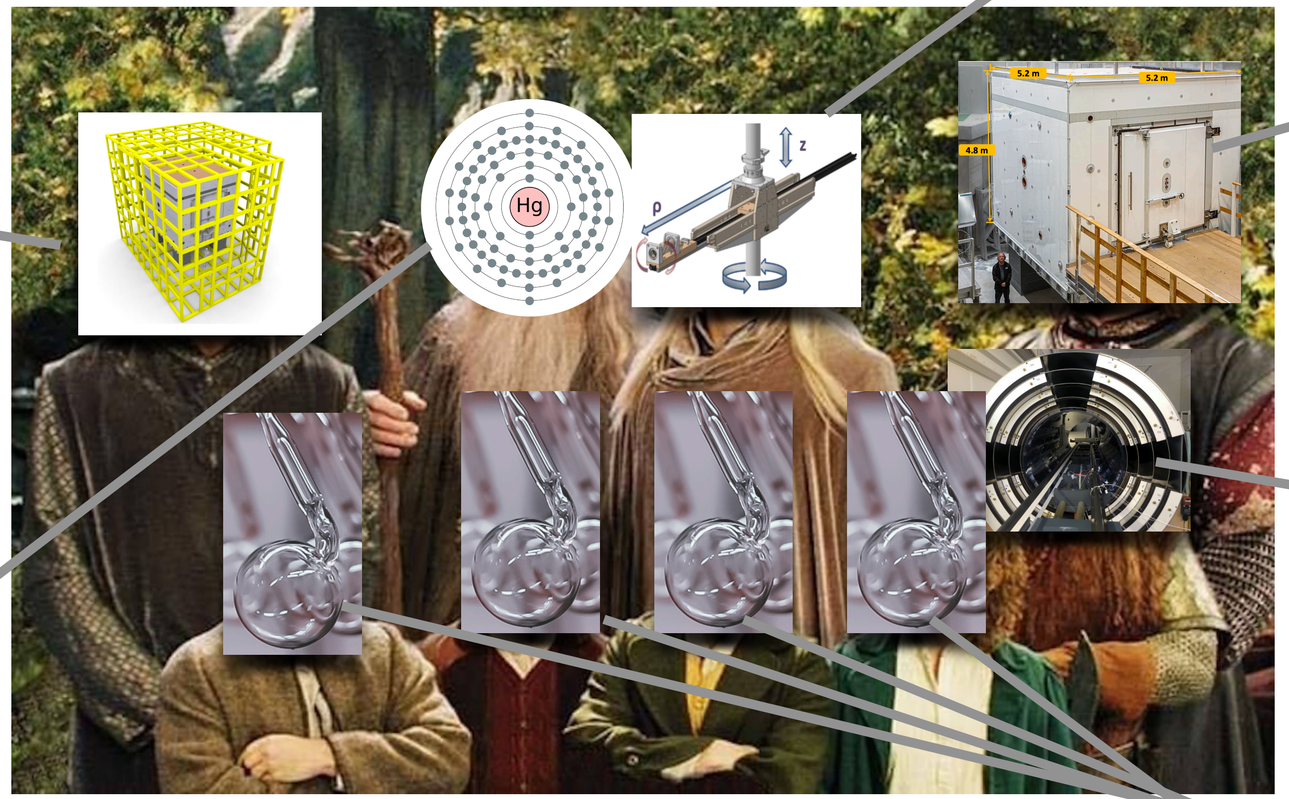

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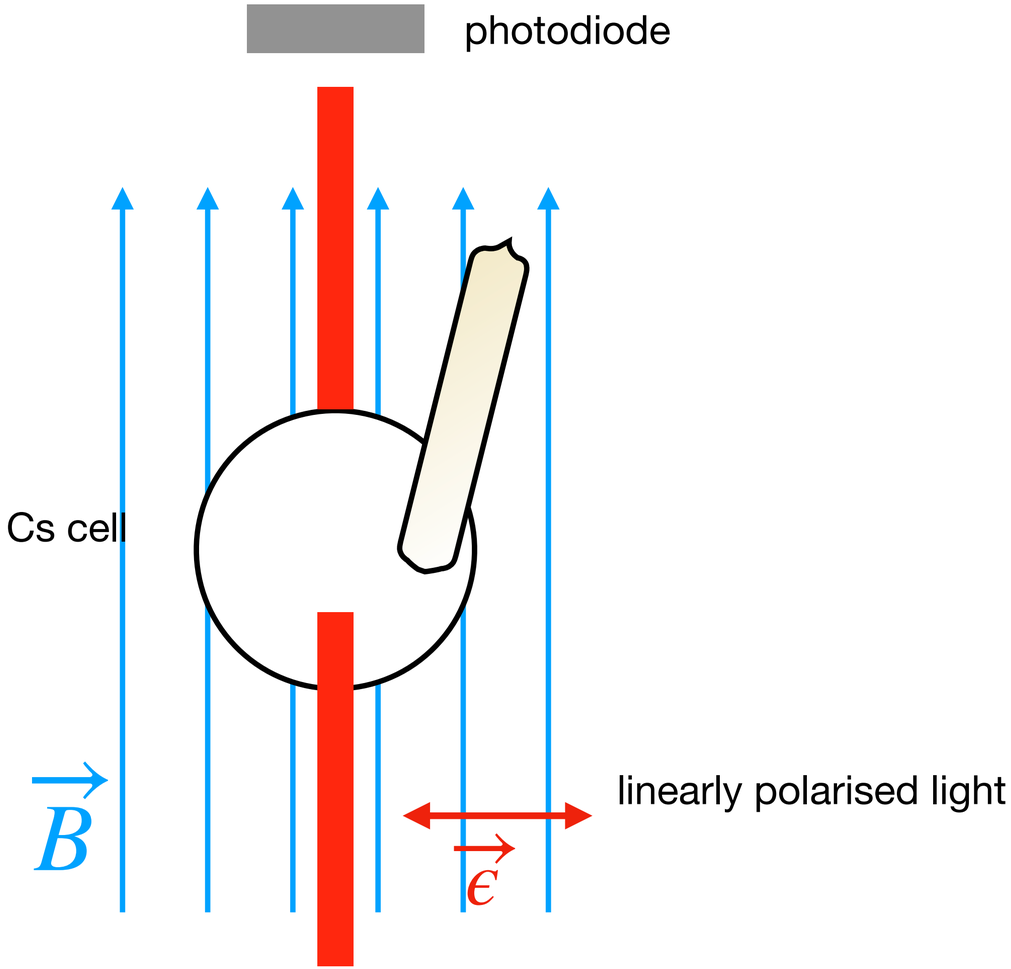
Mercury magnetometer
online magnetic field measurements

Cesium magnetometers
online magnetic field measurements (higher order gradients)

Cesium magnetometer: intuitive physics picture



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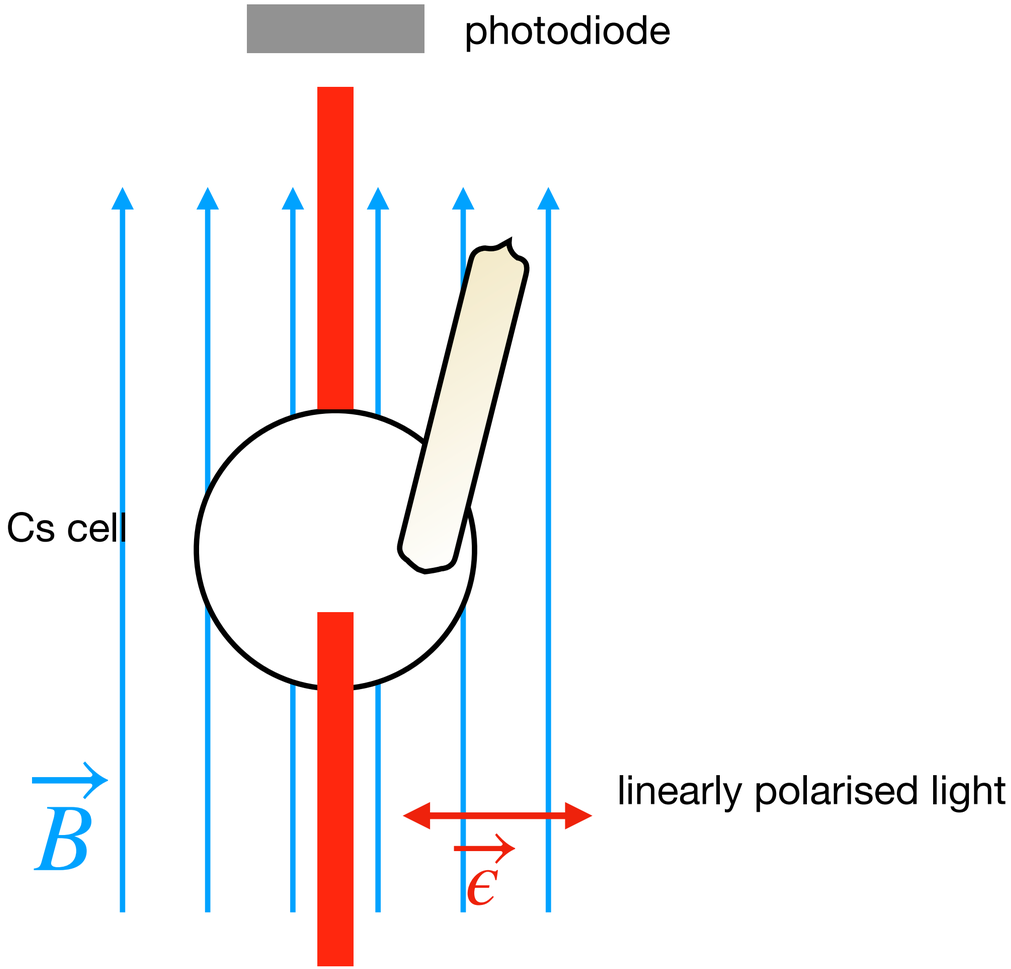

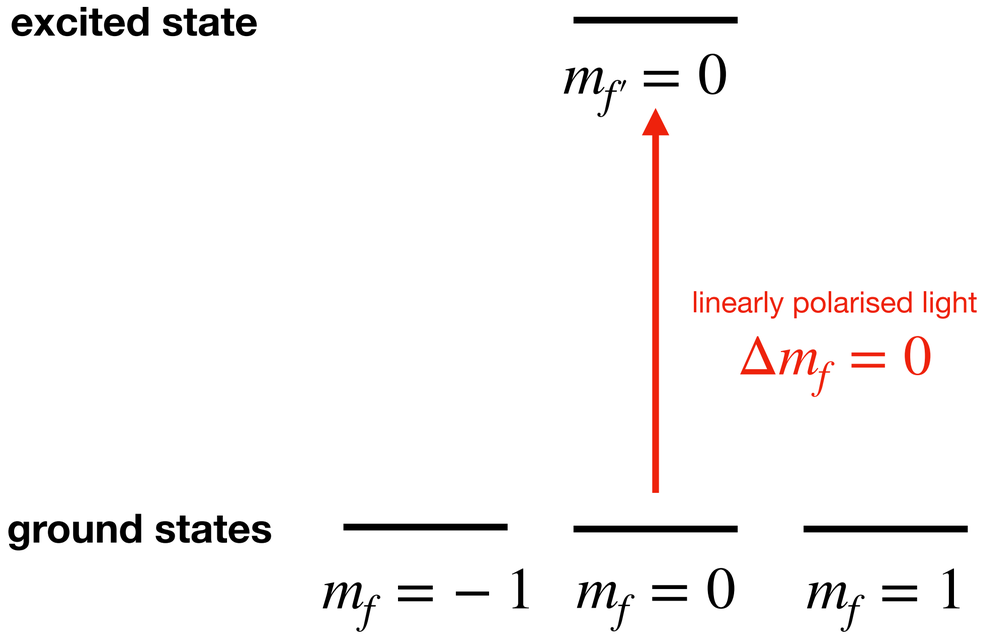

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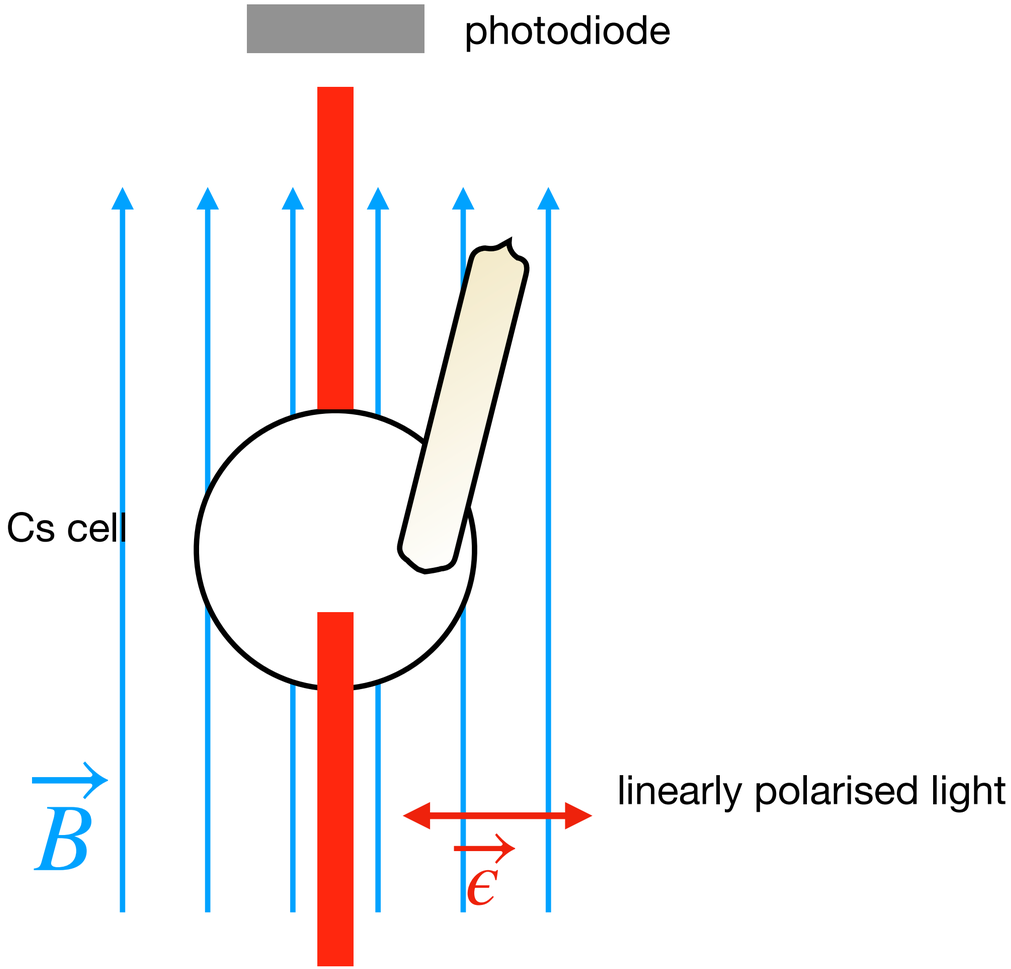

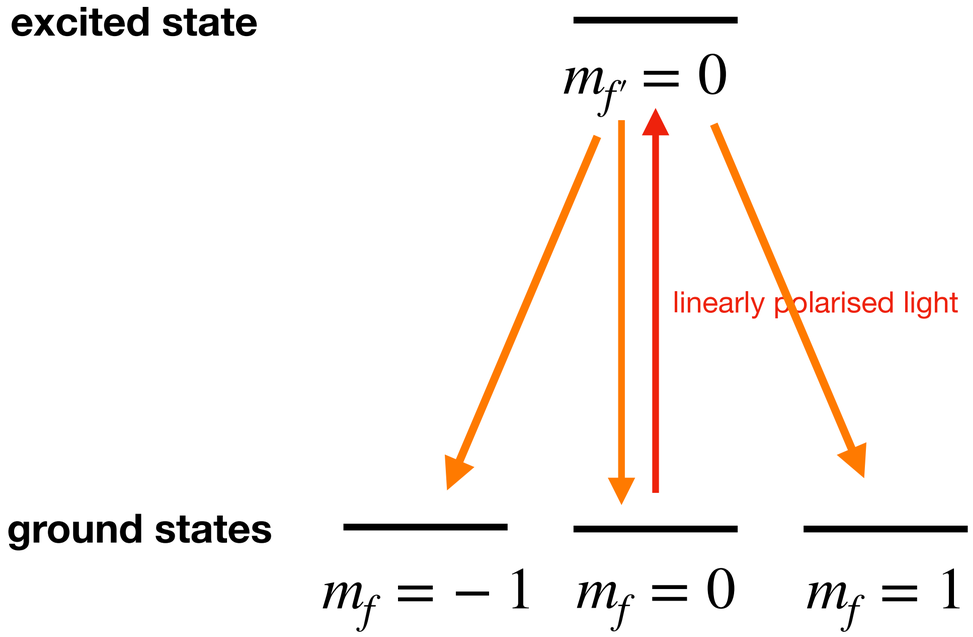

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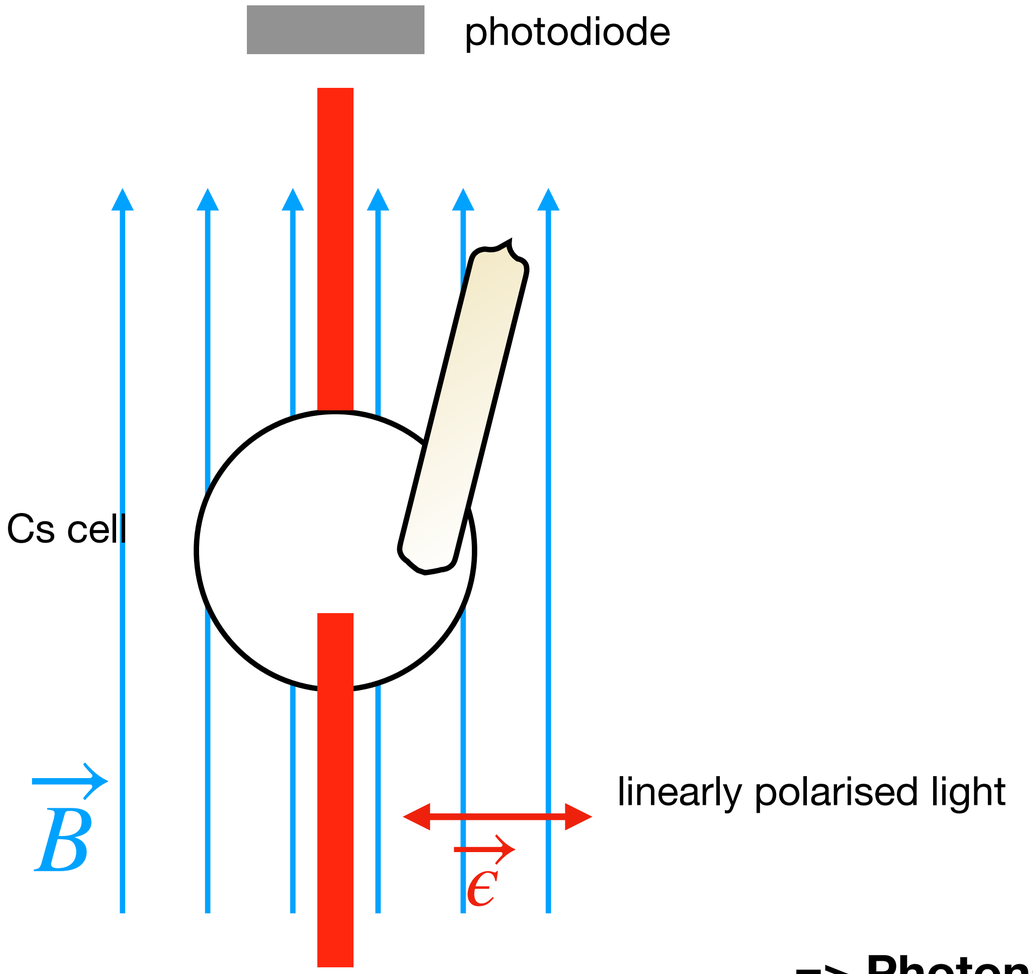
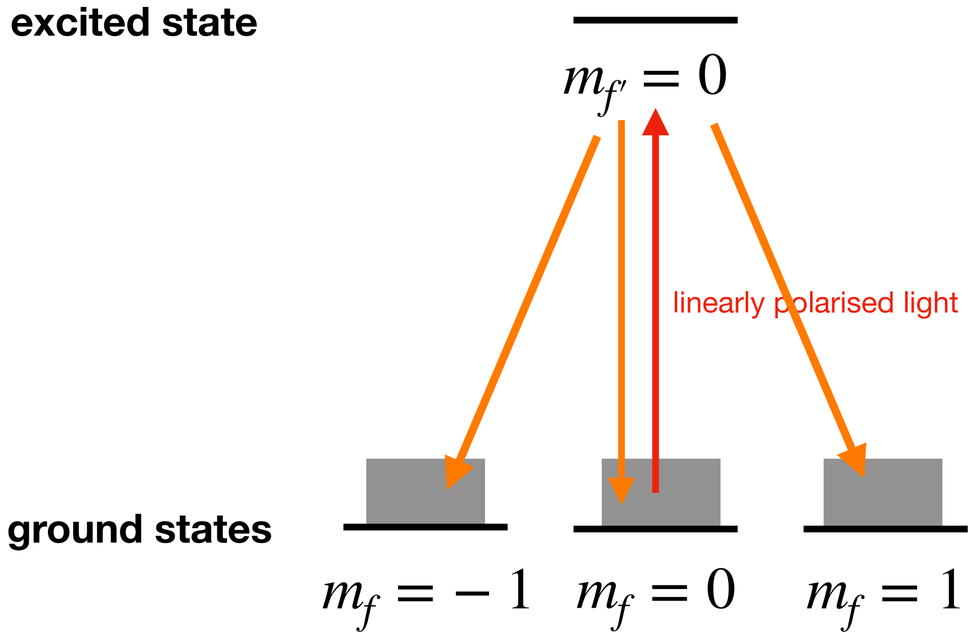
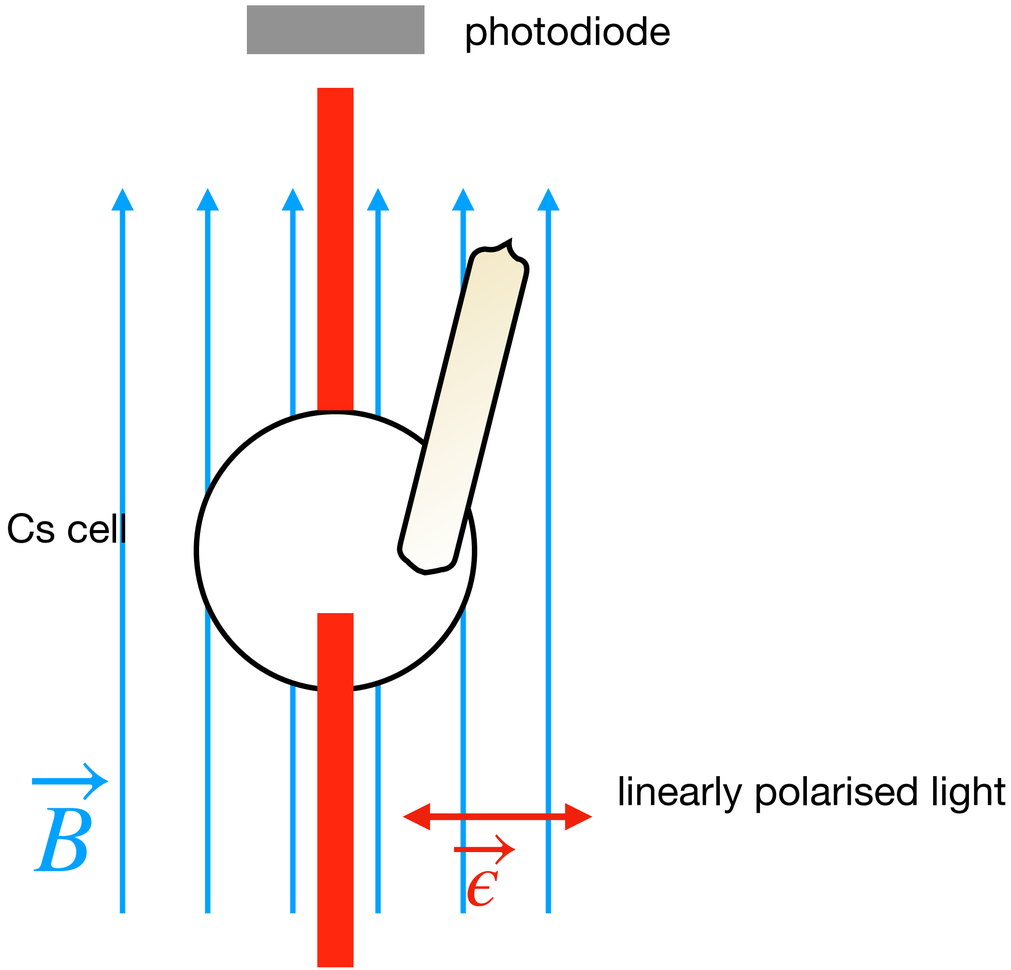


t = 0

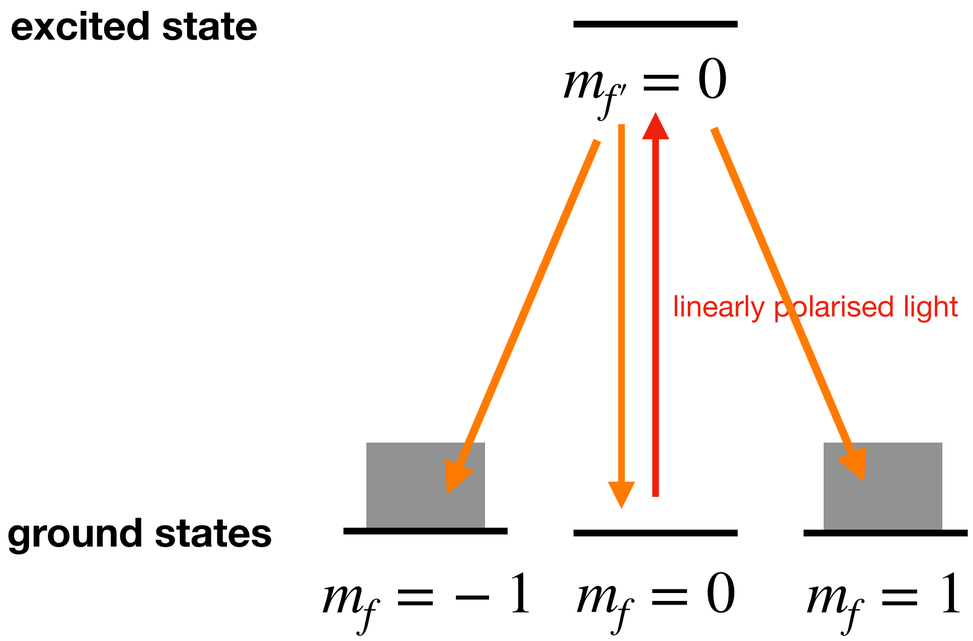


=> Photons start being absorbed, laserlight at photodiode gets dimmer

Cesium magnetometer: intuitive physics picture

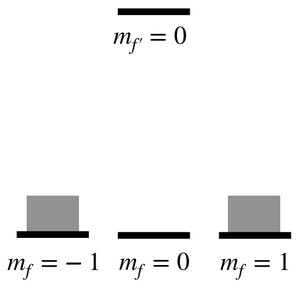


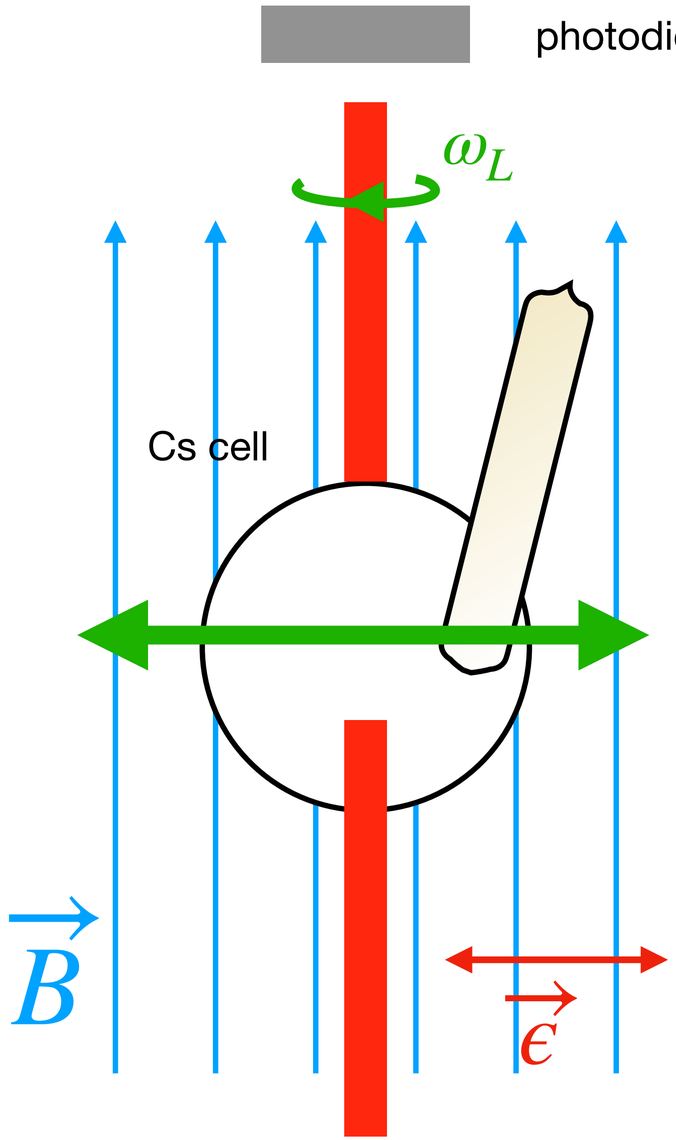
t = later



=> Laserlight at photodiode gets brighter again

Cesium magnetometer: intuitive physics picture





$$\omega_L = \frac{\gamma_{Cs}}{\hbar} B$$

Photodiode would see:

$$I(t) = I_{offset} + A\sin(2\omega_L t + \phi)$$

extract B from here

Cesium magnetometer: intuitive physics picture

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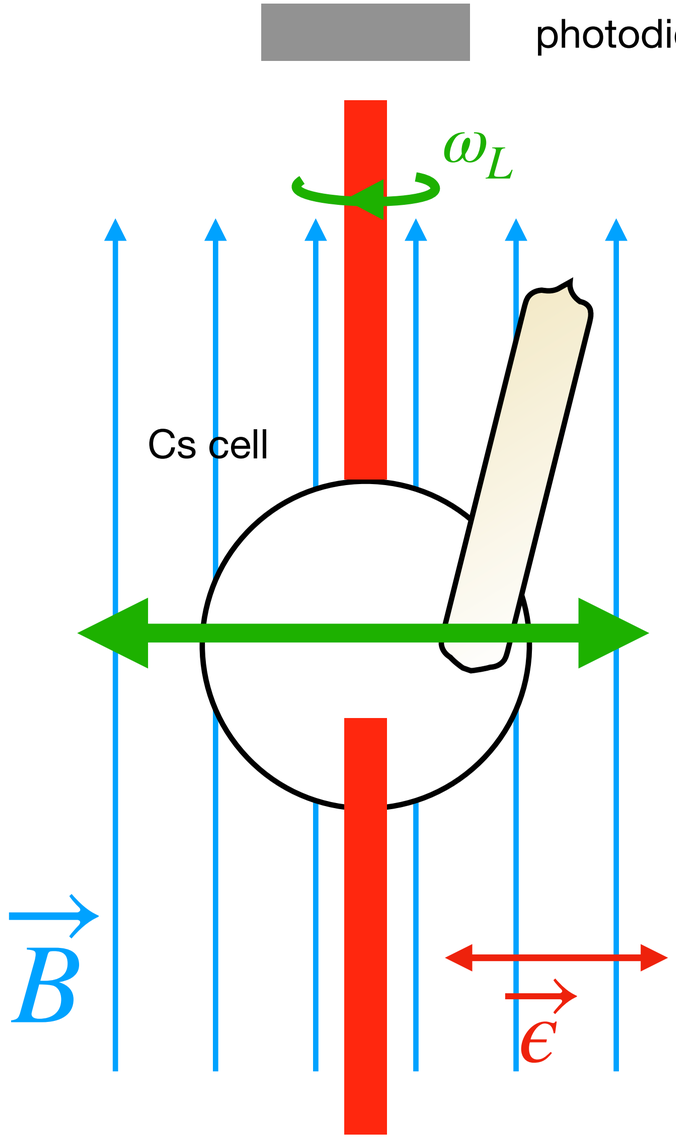

Issue: with precession, we can't laser pump continuously

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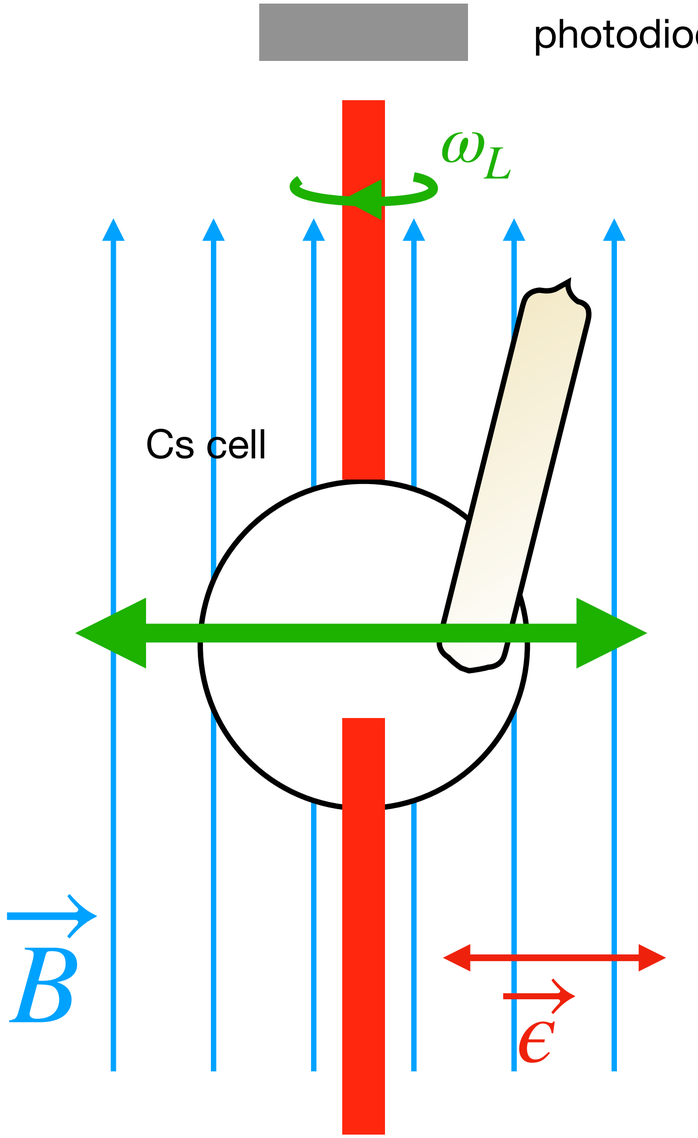
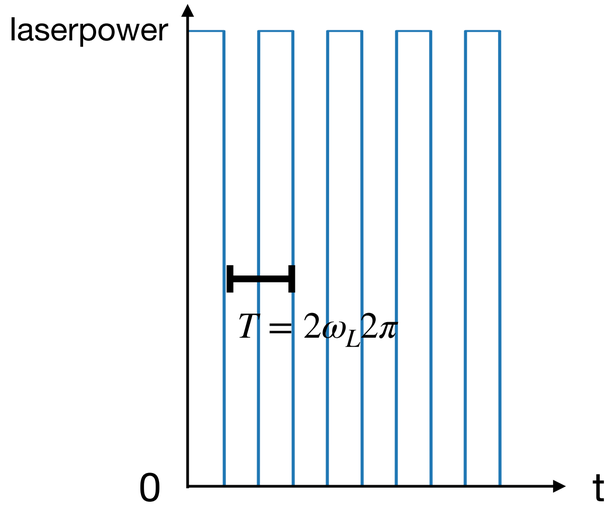


- **Issue: with precession, we can't laser pump continuously**

- **Solution: pump with amplitude modulated laser**
  Literally, turn laser on and off with angular frequency $2\omega_L$ (or close estimation)



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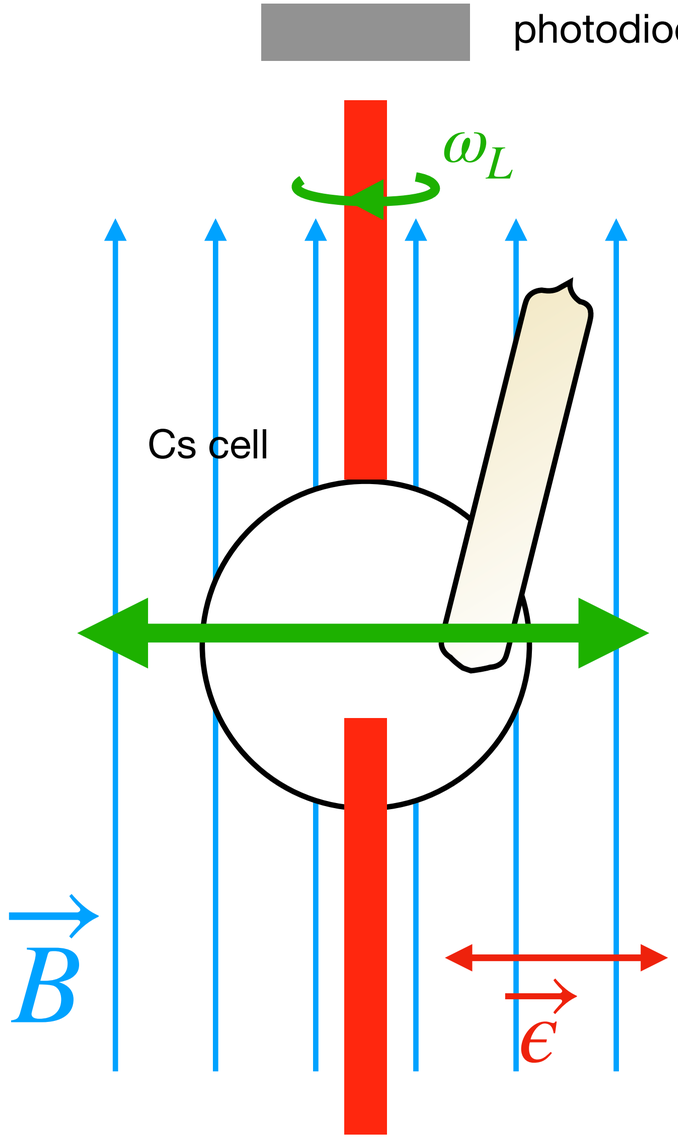

- **After pumping: alignment successfully created**
- **Switch to lower laserpower and observe sinusoidal signal**

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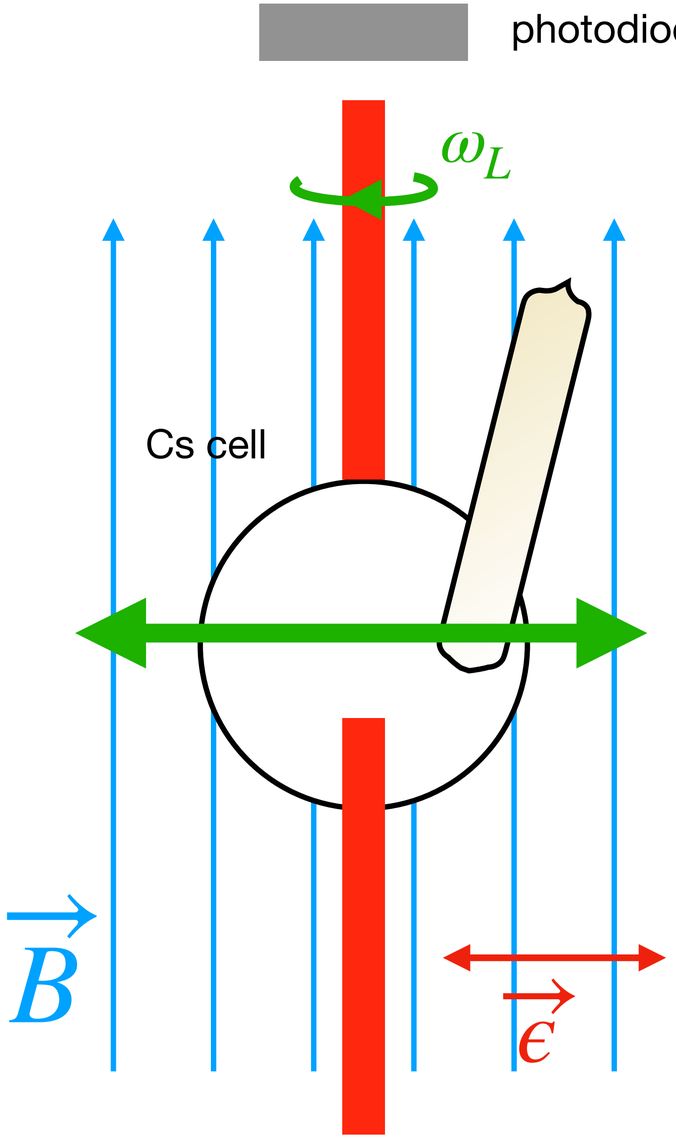
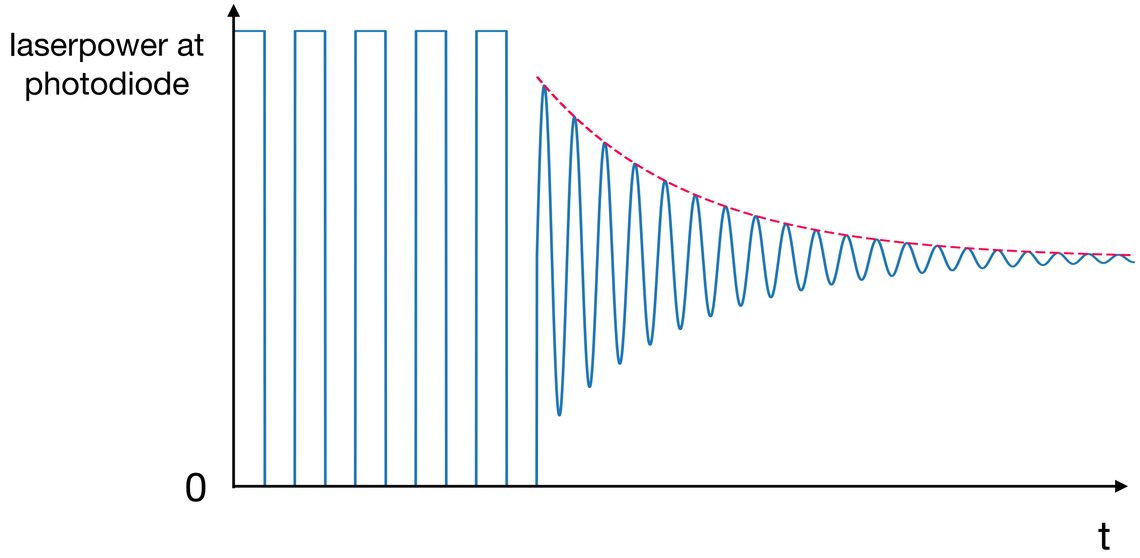


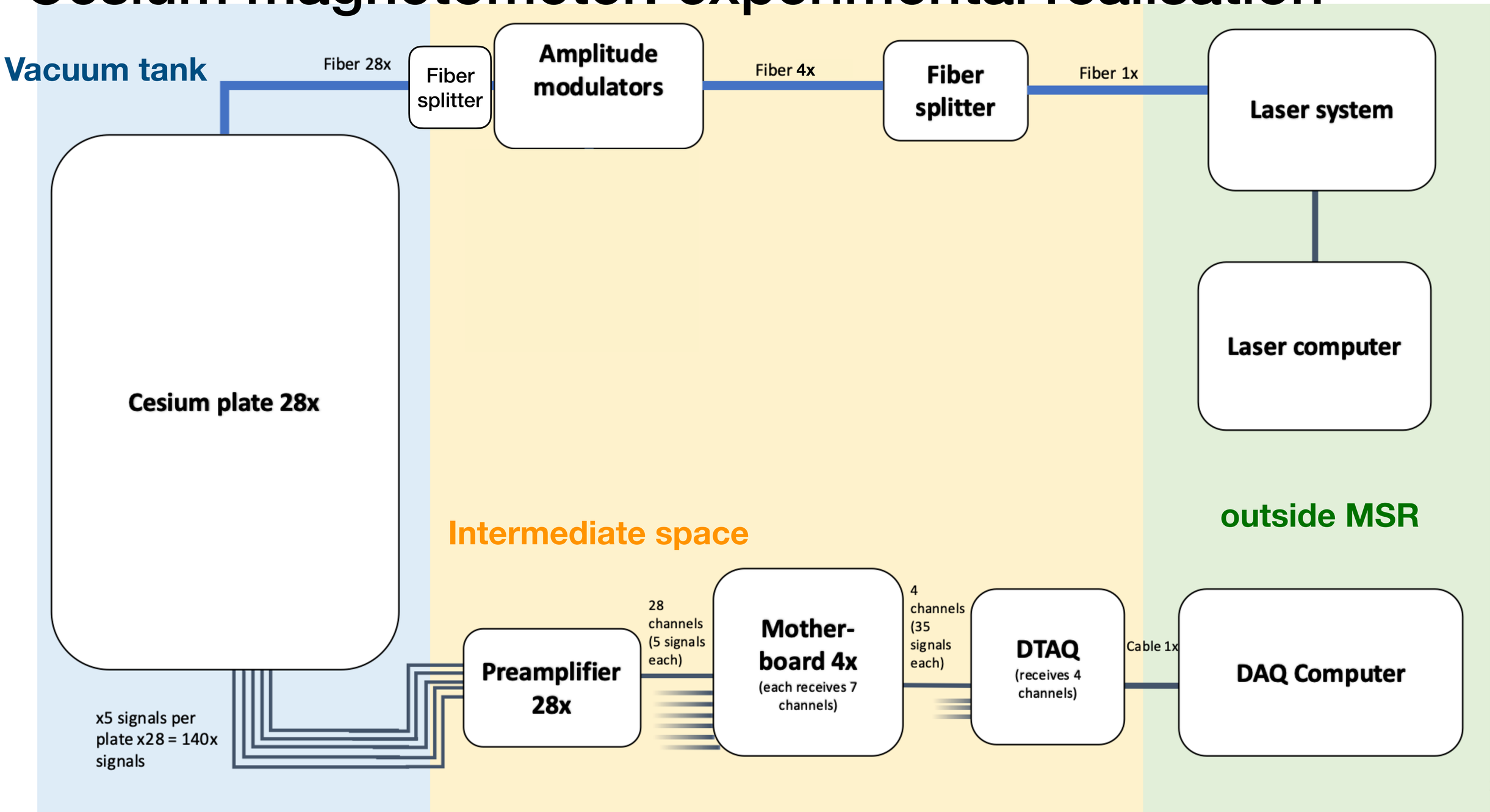
- **After pumping: alignment successfully created**
- **switch to lower laserpower and observe sinusoidal signal**

But: decoherence processes make us lose our alignment (wall collisions, decays to other states etc)

$$I(t) = I_{offset} + Ae^{-t/T_2}\sin(2\omega_L t + \phi)$$



Cesium magnetometer: experimental realisation



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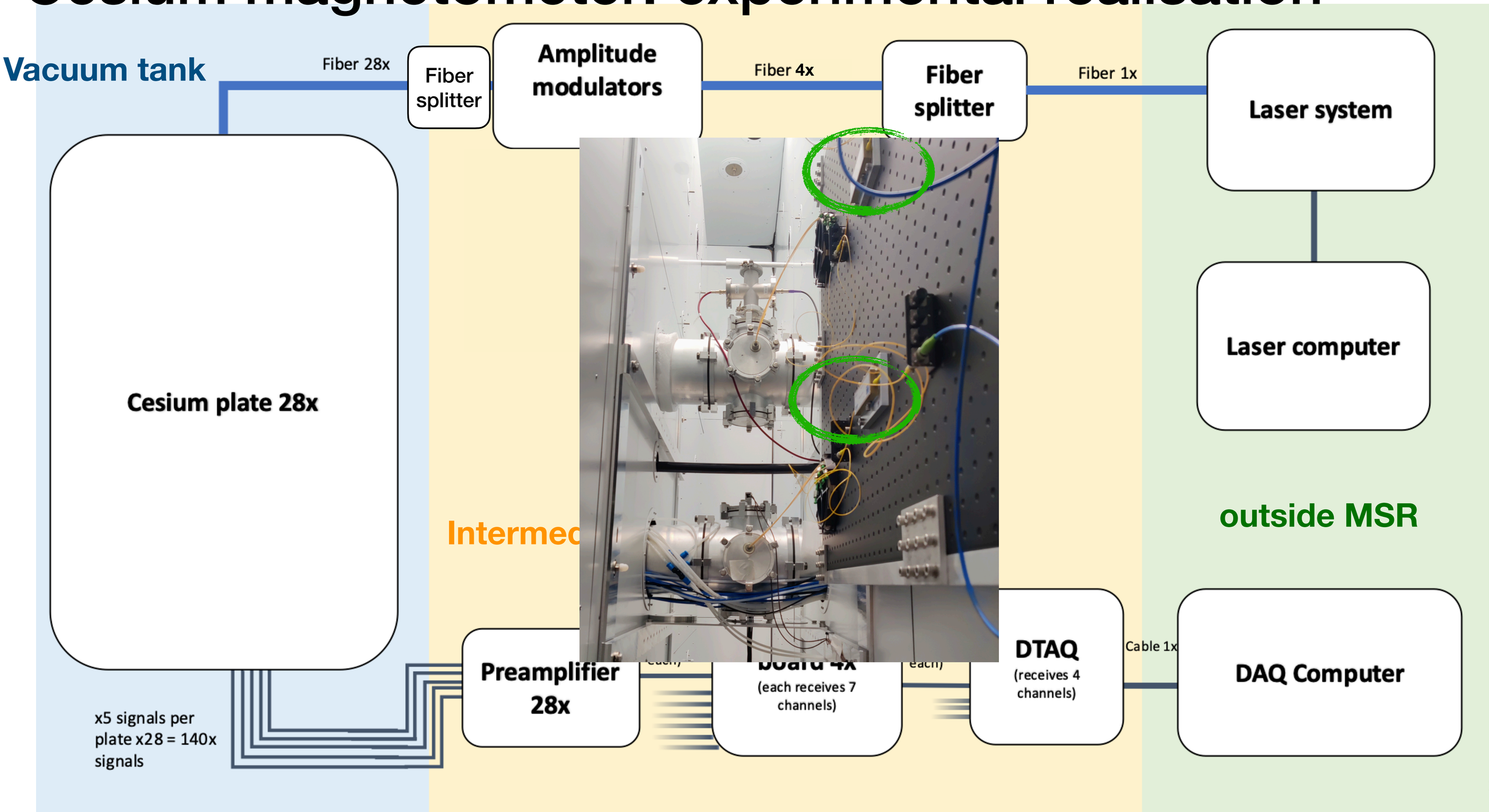

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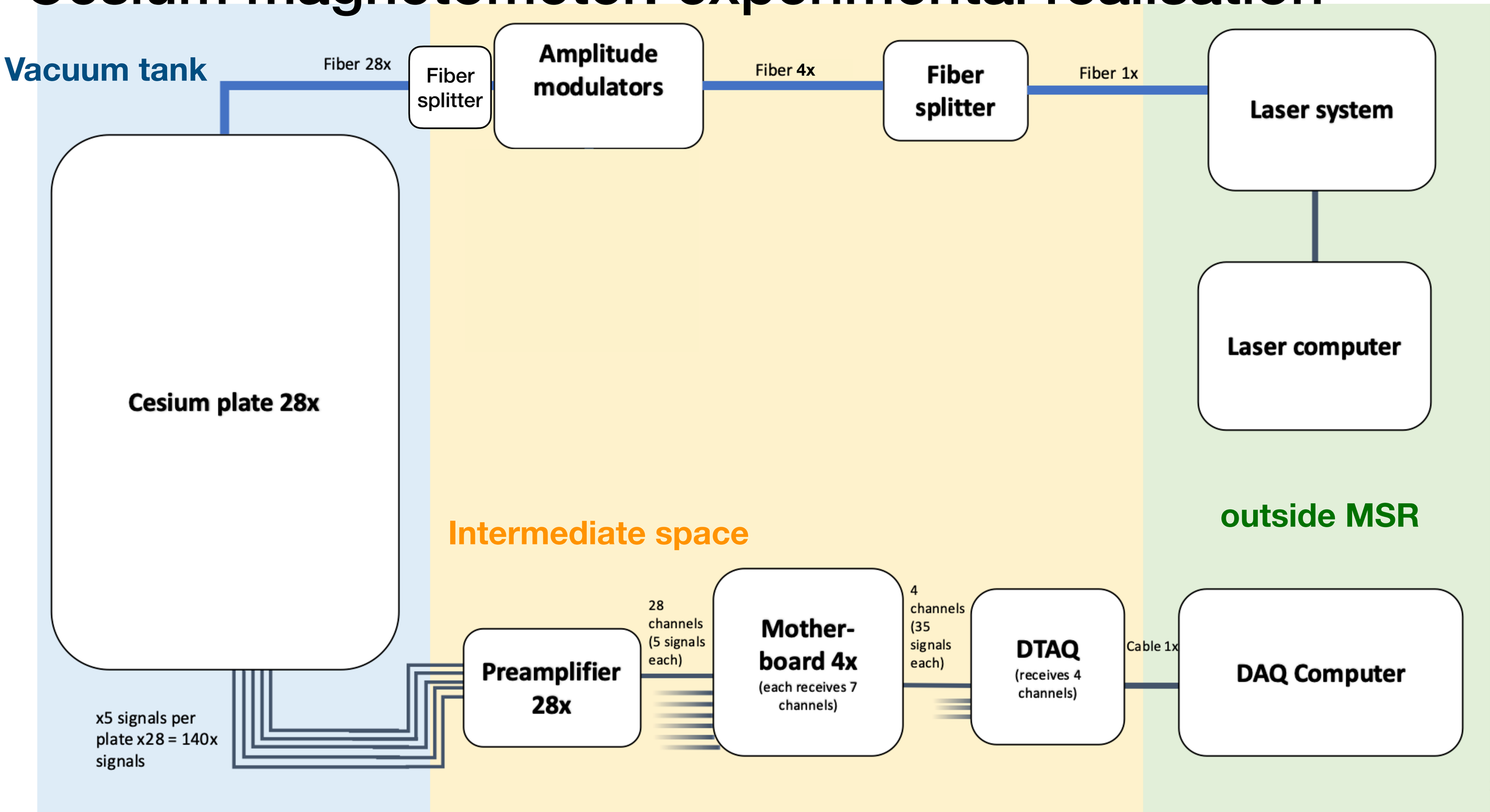

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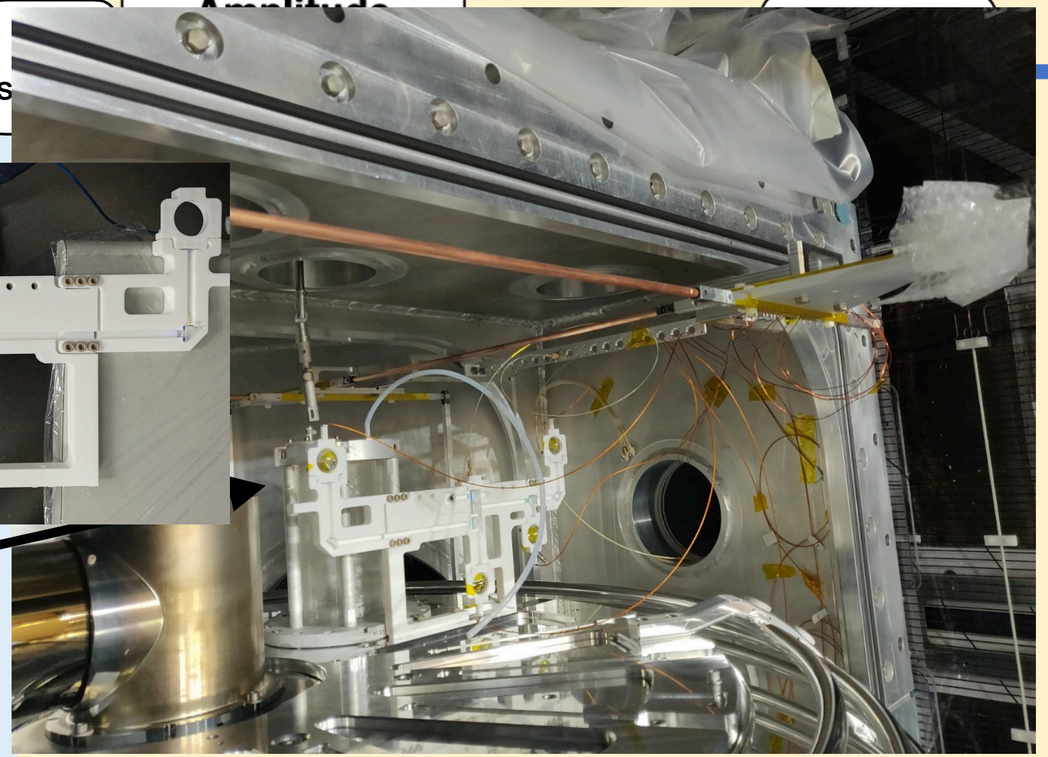

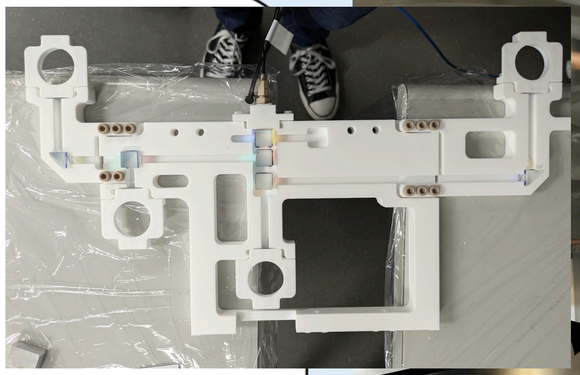

Vacuum tank

Fiber 28x

Fiber 1x

Laser system

Laser computer

Cesium plate 28x

Intermediate space

outside MSR

x5 signals per plate x28 = 140x signals

Preamplifier 28x

28 channels (5 signals each)

Mother-board 4x (each receives 7 channels)

4 channels (35 signals each)

DTAQ (receives 4 channels)

Cable 1x

DAQ Computer

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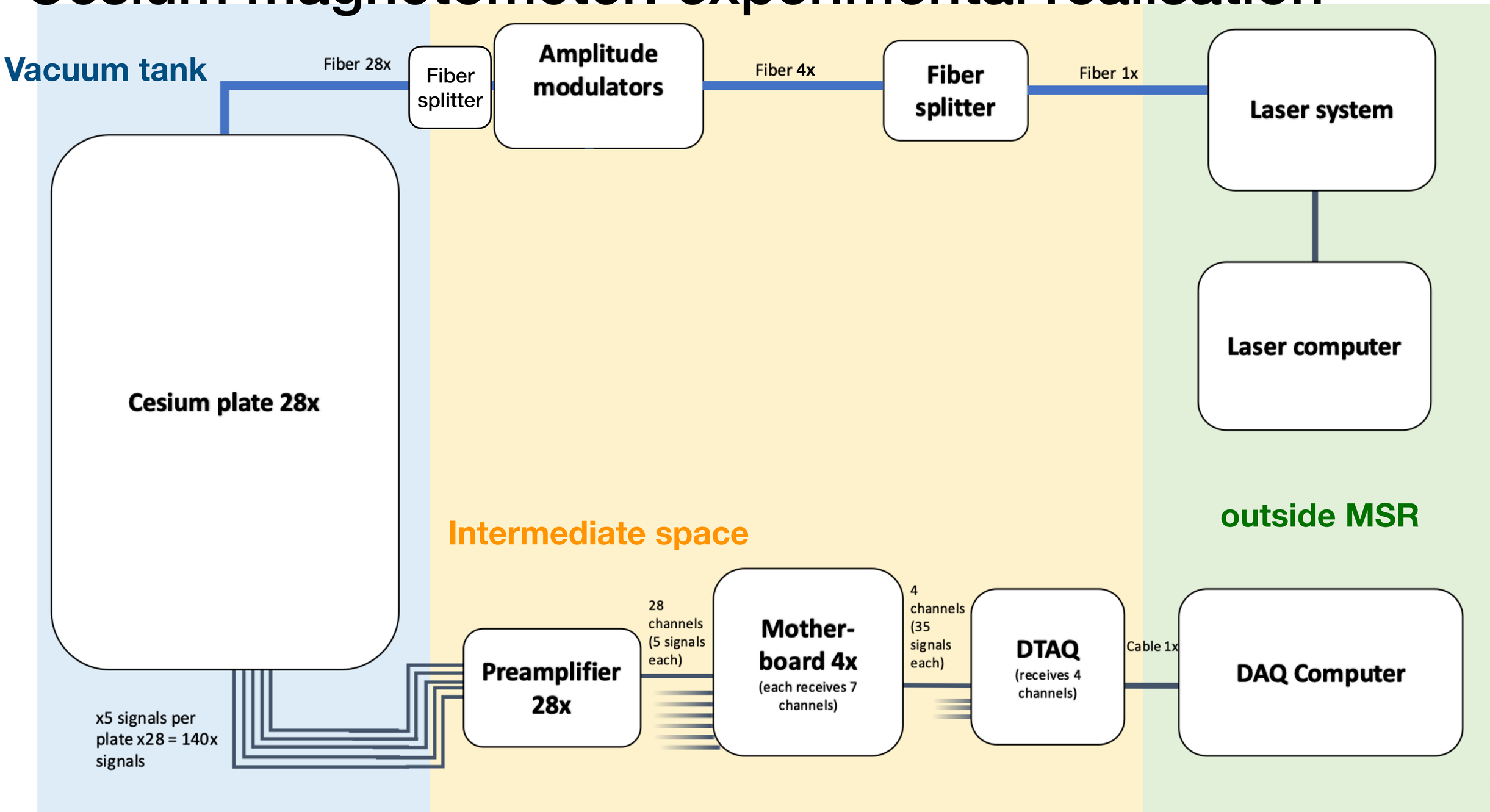

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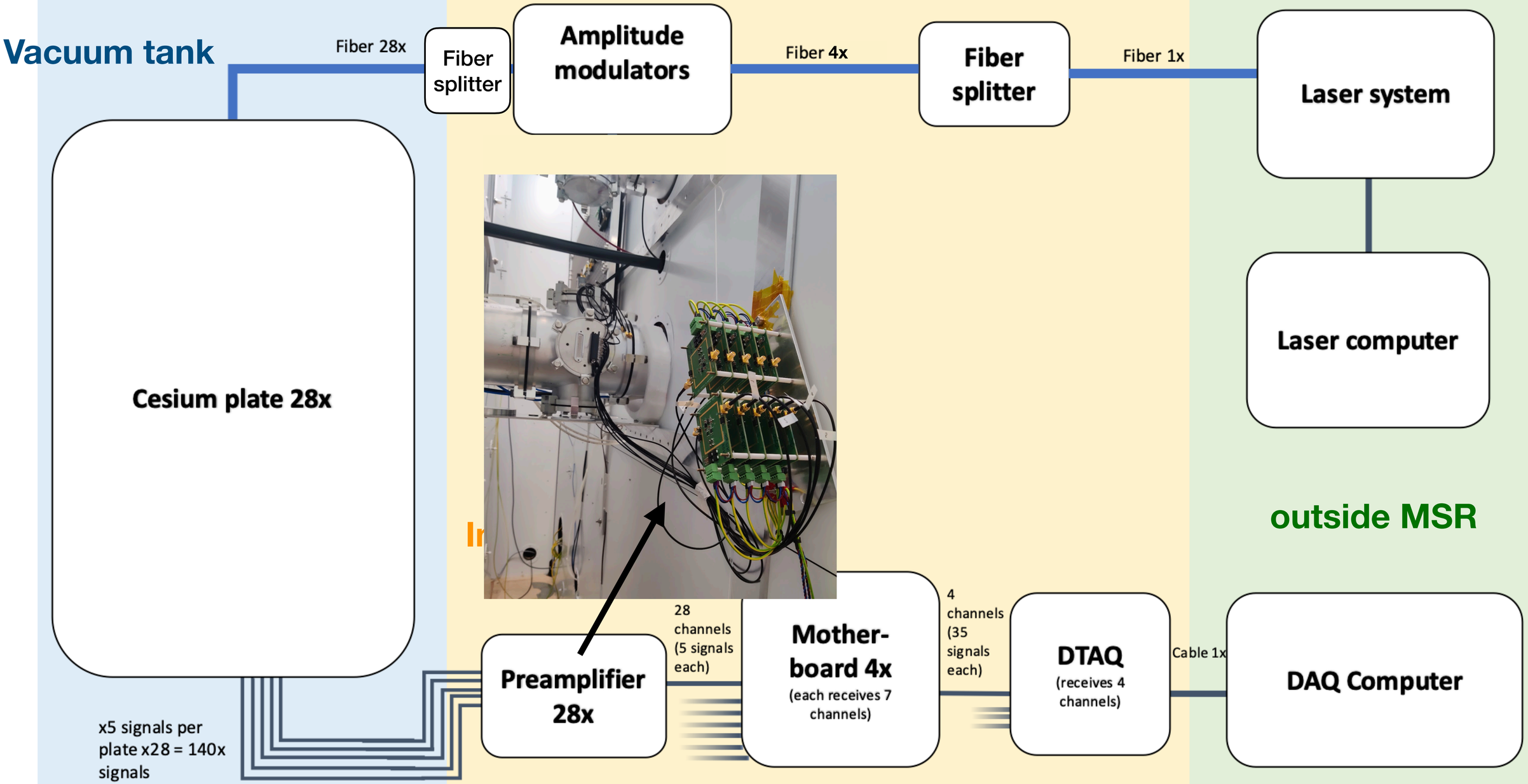

Thank you!