# A device for magnetic-field angle control in magneto-optical filters using a solenoid-permanent magnet pair

QUANTUM LIGHT AND MATTER

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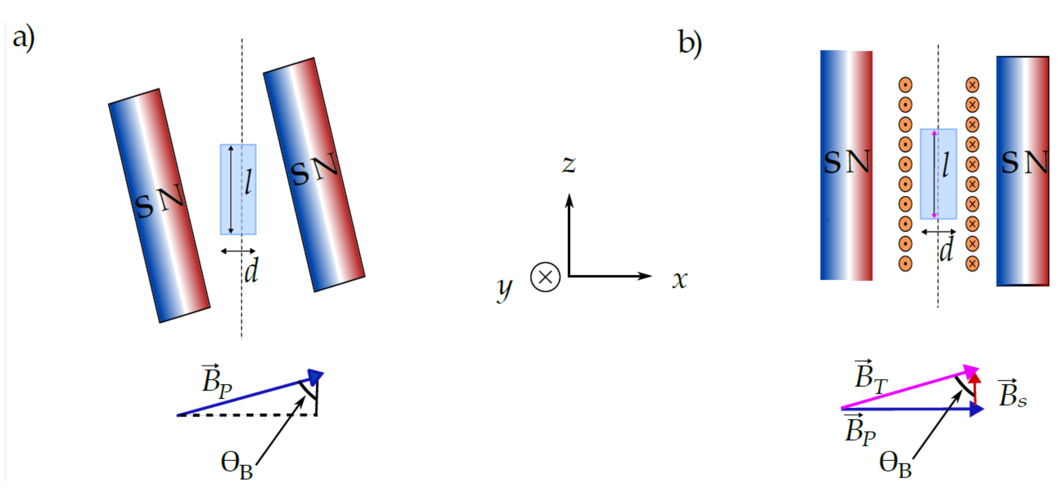
## Motivation

- Atomic bandpass filters are useful for narrow bandwidths and high transmission at specific frequencies [1].
- Most atomic filters use Faraday (Voigt) geometry [2][3].
- We use ***ElecSus*** to design atomic filters [4].
- Interest has grown in filters that use magnetic fields at arbitrary angles, which are frequently produced by physically rotating permanent magnets relative to the laser beam's *k*-vector [5] as in figure (a)
- This method has a limited magnetic-field angle due to decreased field uniformity across the cell as the rotation angle increases.

- **Our new method uses a combination of solenoid and permanent magnets to create adjustable small axial field and large transverse field respectively as in figure (b)** [6].
  - This method improves angle control and precision in filter profile sensitivity.
  - larger angles can be created
  - longer vapor cells can be used

***ElecSus* download here:**



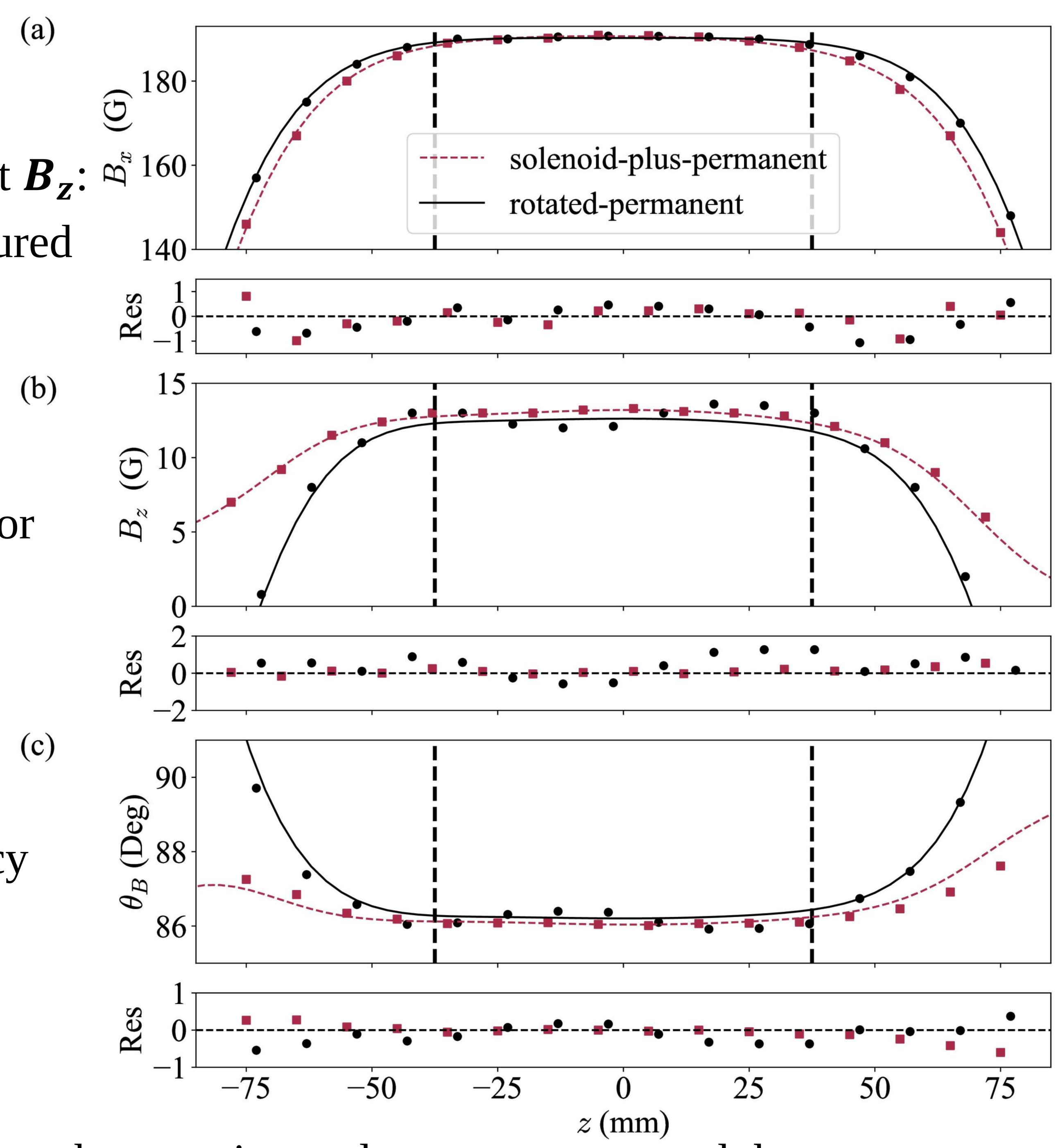

## Hall probe measurements

(a) Transverse field component $\boldsymbol{B_x}$:
- The maximum value of two configurations =**190 G**
- Field homogeneity maintained at 1.5% over the region occupied by the vapor cell.

(b) Axial field component $\boldsymbol{B_z}$:
- The maximum measured value= **13 G**

(c) $\boldsymbol{\theta_B} = \tan^{-1}(B_z/B_x)$
- Approximately **86°** for both geometries
- RMS error of 0.2°.

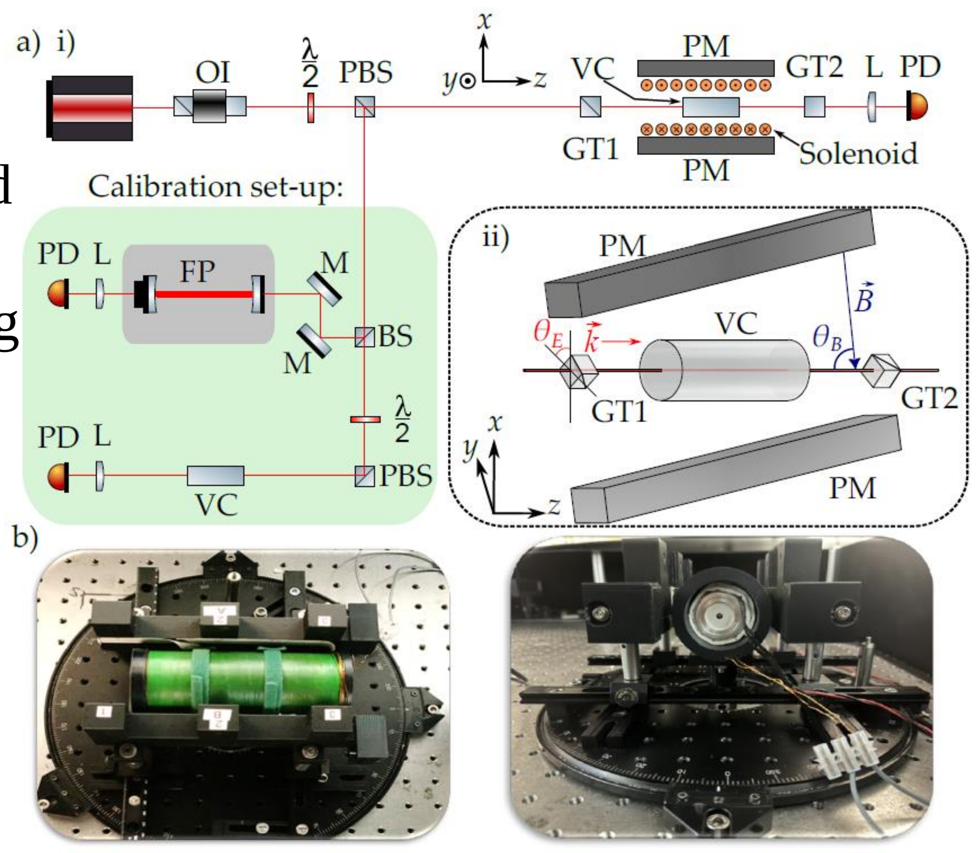
- Uniformity and accuracy of the magnetic fields produced by the two configurations

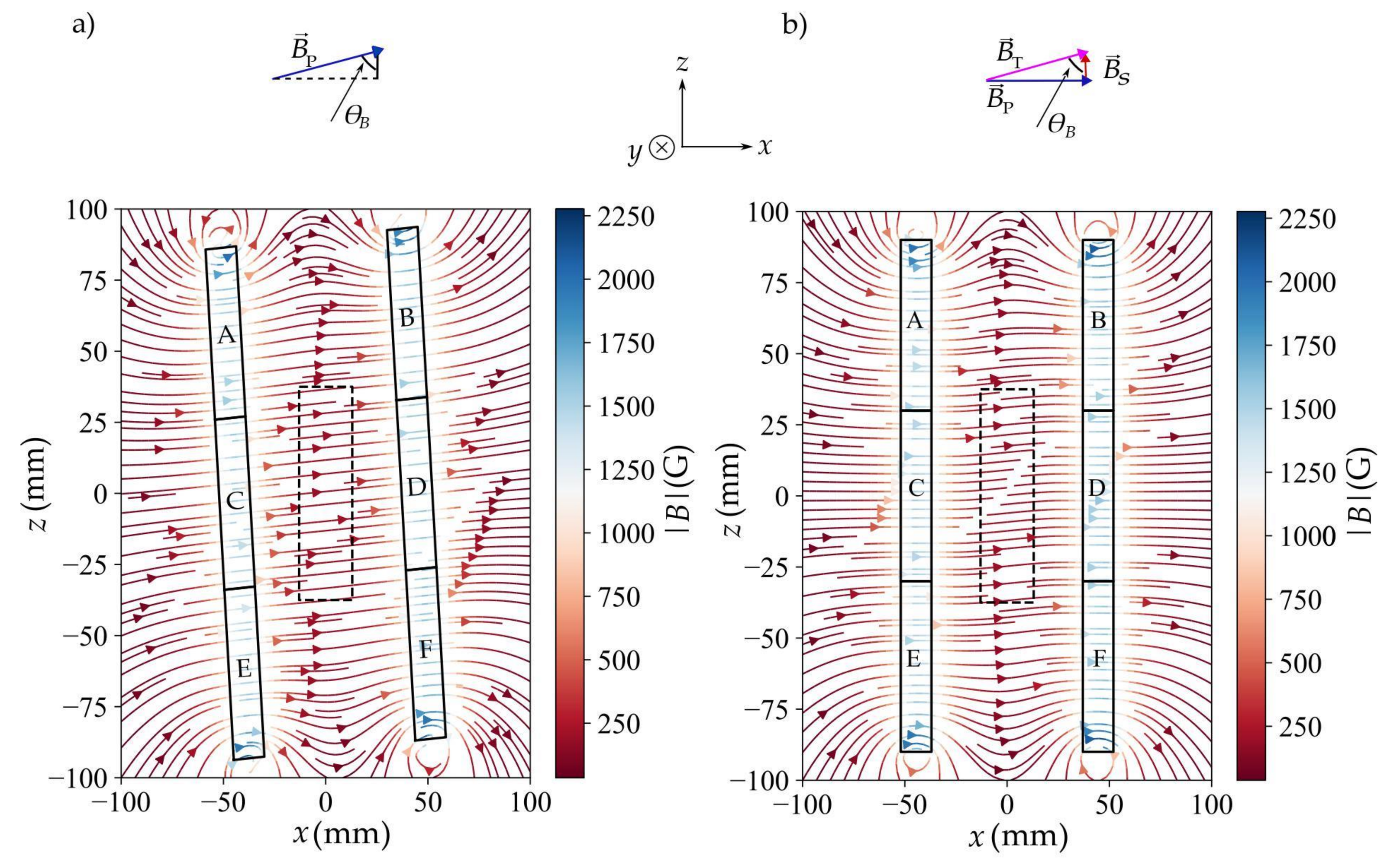



- Good agreement between the experimental measurements and theory

## Magpylib simulation of the magnetic field

- The Voigt permanent magnet configuration:
  - Six cuboidal magnets; each three are stacked along the z-axis
  - Mounted on a rotating breadboard with a removable centre portion.
  - Separation between magnets along x-axis = 74 mm
- Vapor cell (VC) fixed relative to the laser beam axis (z-axis)
- Solenoid between the pair of permanent magnets produce $B_z$
- VC and solenoid mounted within the centre portion of the rotating breadboard

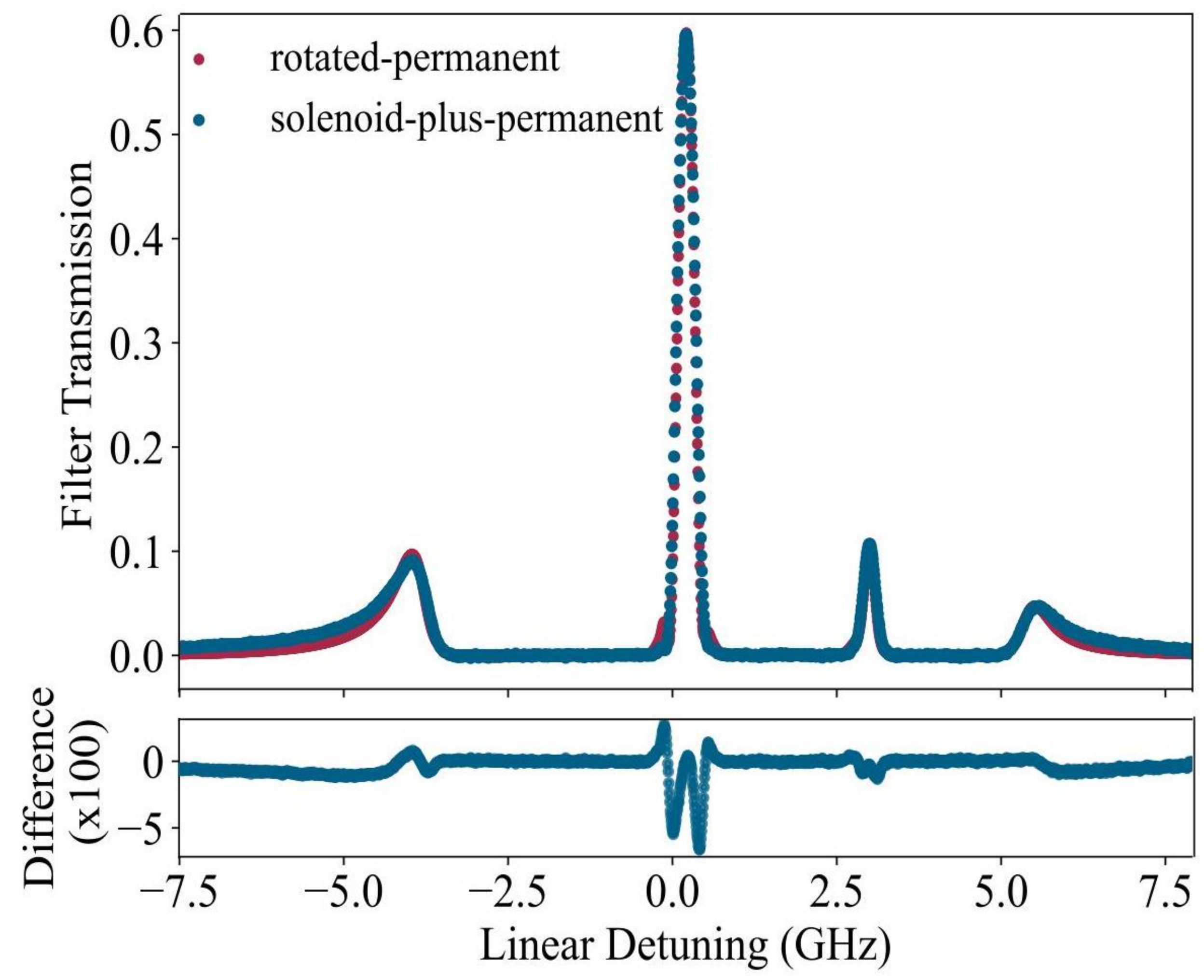


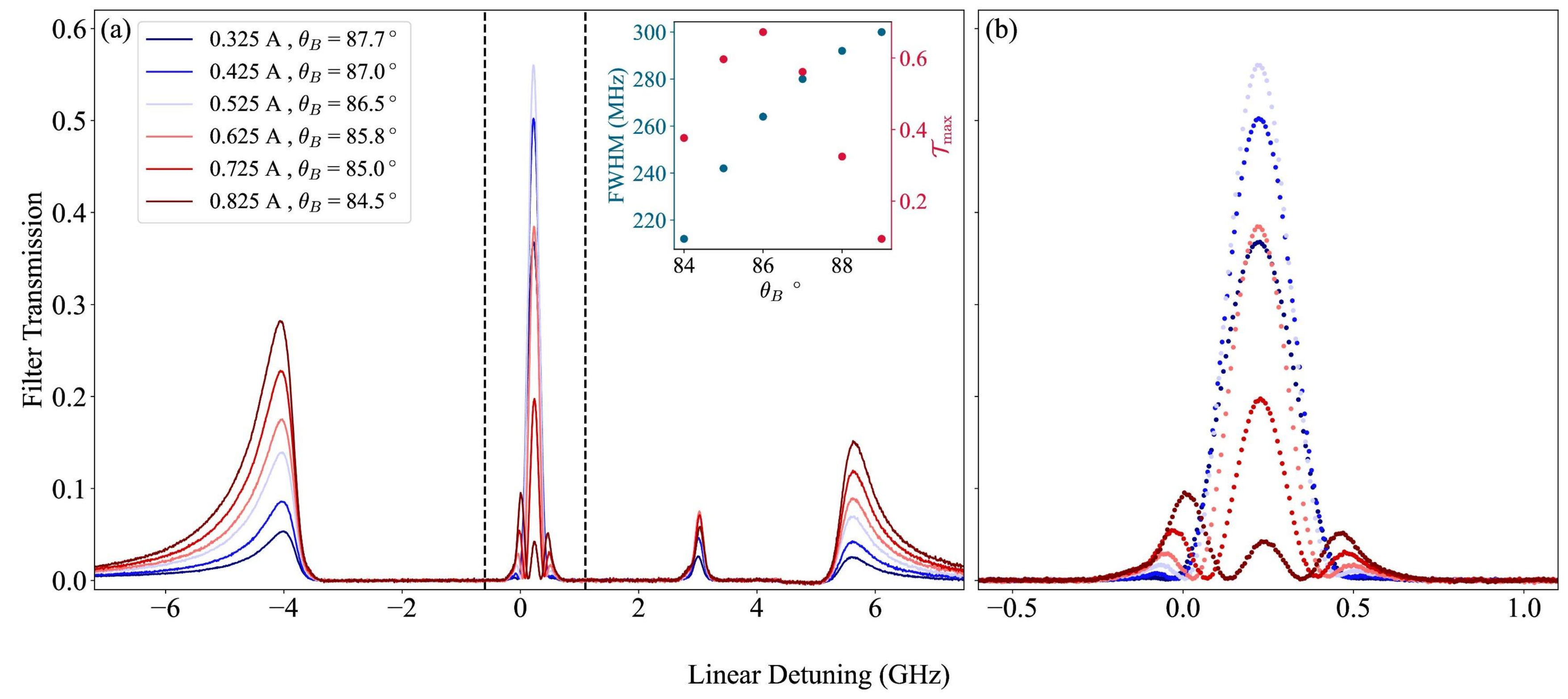

(a) ***Magplib*** [7] simulations of the rotated permanent configuration.
(b) solenoid-plus-permanent configuration
- The field magnitude and direction along the vapor cell are nearly identical for both configurations.

## Magneto-optical filter measurements

Below:
- a comparison between the two experiments.
- excellent agreement of producing all the expected transmission features.




Below:
- The varied filter spectra produced by the solenoid-plus-permanent configuration with different current.
- Increasing the solenoid current raises:
  - The height of the central peak and the other peaks
  - The main peak's width
  - At $I$= 0.625 A ($\theta_B$ = 85.8), the central peak's transmission starts to decrease, while the wing peaks continue to rise
- **Shows more efficient and rapid tuning capabilities**




## References

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