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Gated Blue Cesium Faraday Atomic Line Filter

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GATED ULTRA-NARROW MAGNETO-OPTIC ATOMIC LINE FILTERS FOR LIDAR APPLICATIONS

- Solar background limited lidar receivers require ultra-narrow linewidth filters to reach quantum limited operation
  - remote sensing
  - active tracking
- Like the conventional absorptive/re-emissive atomic line filters (ALF), the M-0 ALFs
  - operate at discrete atomic absorption lines
  - have Doppler limited passbands
  - high out-of-band rejection
- However, M-0 ALFs are imaging filters with
  - very high peak transmission
  - wide field-of-view
  - filter bandwidth limited signal bandwidth
- Dynamic range limited receivers benefit from programmable gain to suppress unwanted signals from nearby sources
  - the gated M-0 ALF transmission can be stepped or ramped to reject early signals

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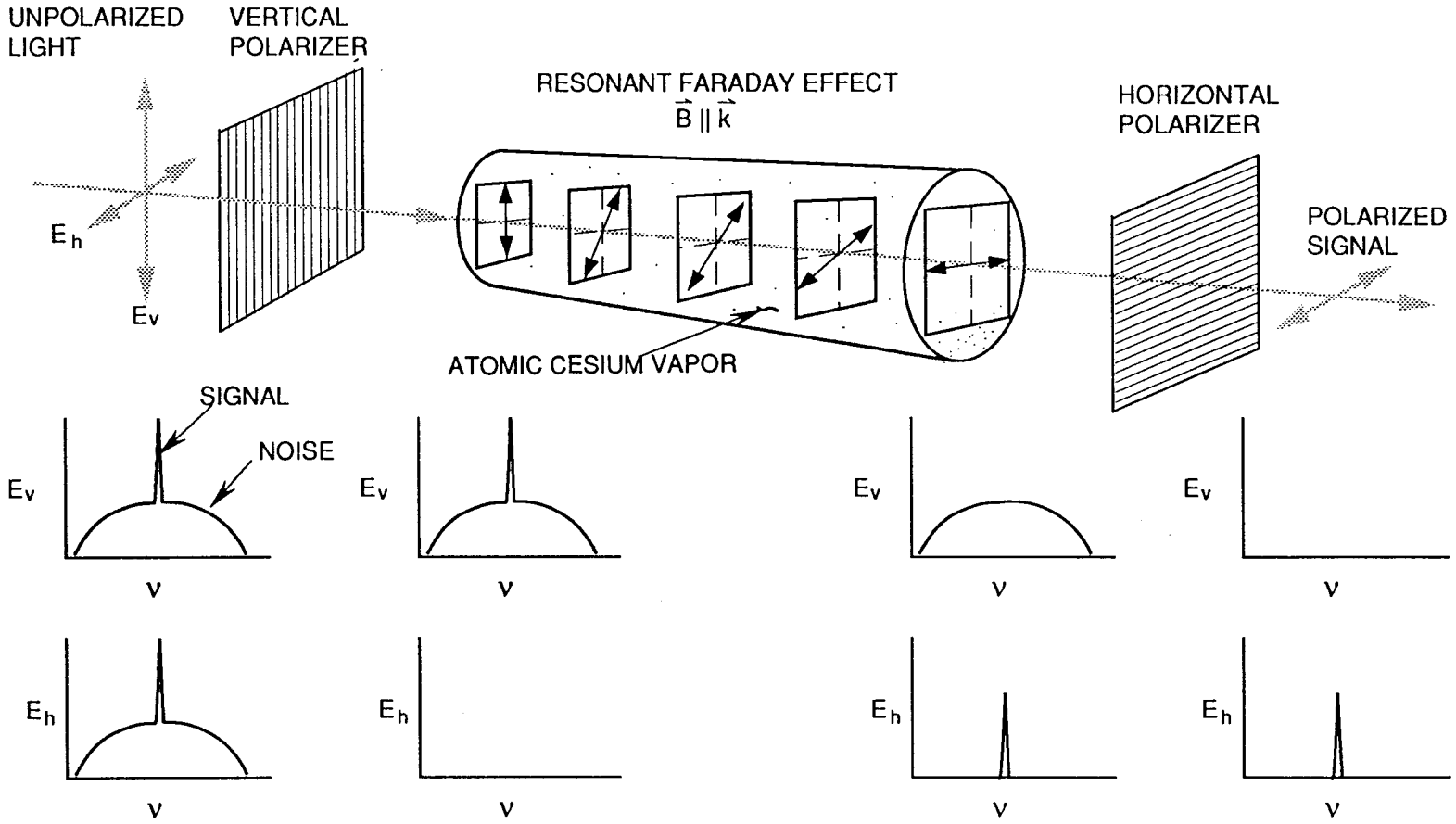
TOPICS

- Principles of Faraday magneto-optic filter operation
- Transmission modulation by field intensity modulation
- Optimizing operating temperature for low field, high transmission
- Pulsed coil design for large (2"ϕ) aperture filter
- Gated filter tests
- Conclusion

PRINCIPLES OF FARADAY MAGNETO-OPTIC ATOMIC LINE FILTER OPERATION



- The magneto-optic element transforms vertical into horizontal polarization over a narrow spectral band
- The resonant Faraday effect is exhibited in near strong absorption lines
- In-band light is transmitted; out-of-band light is blocked
- This work concerns the cesium Faraday filters with resonances at 455 nm and 852 nm

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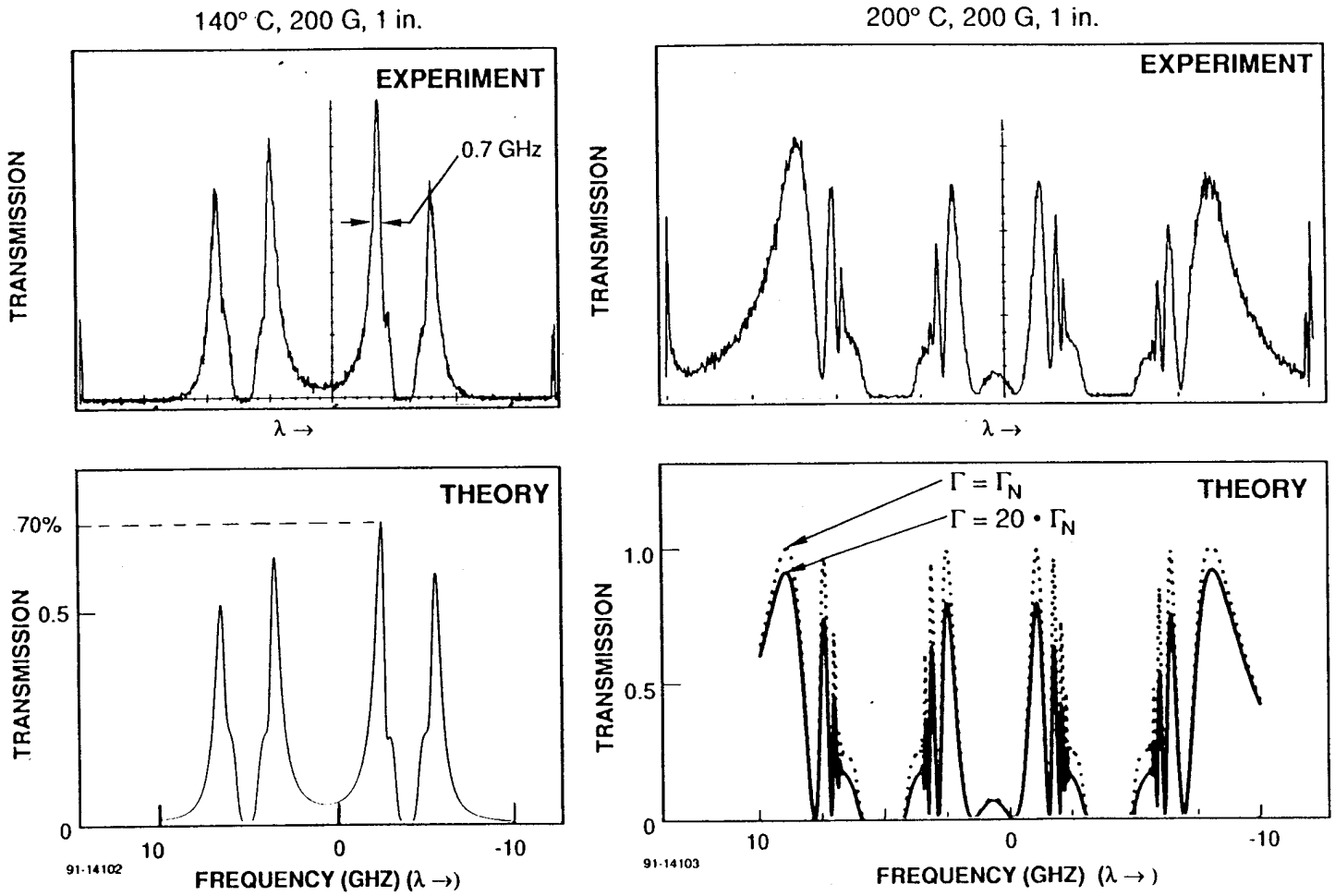
BLUE FARADAY FILTER SPECTRA ARE WELL PREDICTED UP TO 200° C



- Optimum conditions minimize bandwidth and maximize transmission
- Modelling above 200° C must allow for collisional broadening
- Additional broadening becomes apparent at temperature T ≥ 200° C

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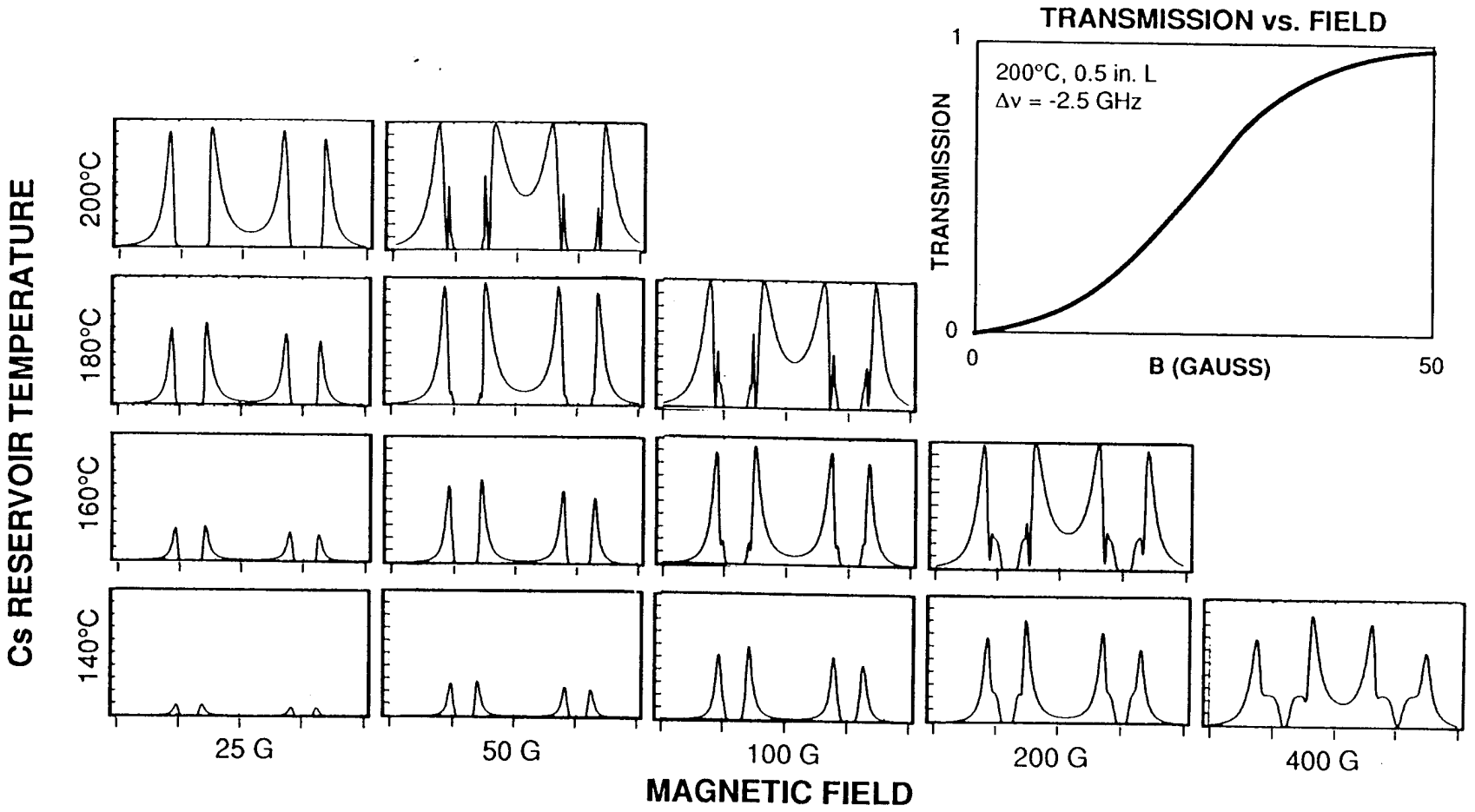
GATING IS ACCOMPLISHED BY FIELD MODULATION



- Calculated blue Faraday filter spectra (0.5 in. L)
- Higher vapor temperatures can be traded for reductions in maximum magnetic field

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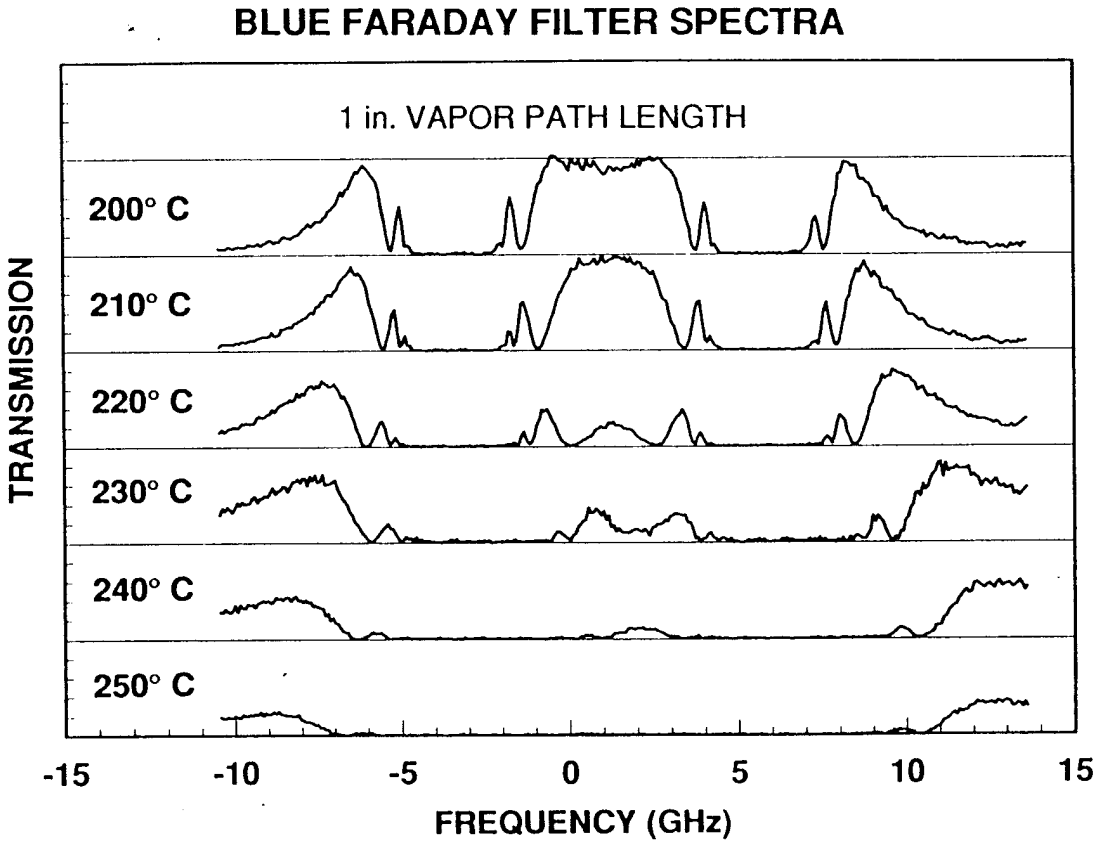
Ref. 91-14099

THE FIELD REDUCTION FOR TEMPERATURE TRADE IS LIMITED BY TRANSMISSION DEGRADATION



- Transmission spectra normalized by combined component transmission
- Increased collisional broadening at higher temperatures extends absorption line wings
  - Peak passband transmission is spoiled

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FAST GATED FIELD GENERATION

- Requirements
  - 50 G longitudinal field
  - Uniform throughout active volume, 1 cm L x 5 cm ϕ (~ 2%)
  - Square pulse field modulation
    - -- risetime: 10 s of nanoseconds
    - -- duration: $\gtrsim$ 1 μs

- Pulsed coil implementation
  - Coil
    - -- single loop Helmholtz-like coils
    - -- Strip conductors for minimum inductance (~ 1/3 μH)
    - -- 250 amp peak current for 50 gauss
  - Current supply
    - -- thyratron switched pulse forming network (PFN)
    - -- ~600 ft spool of 50 Ω coax PFN
    - -- < 35 kV charge voltage

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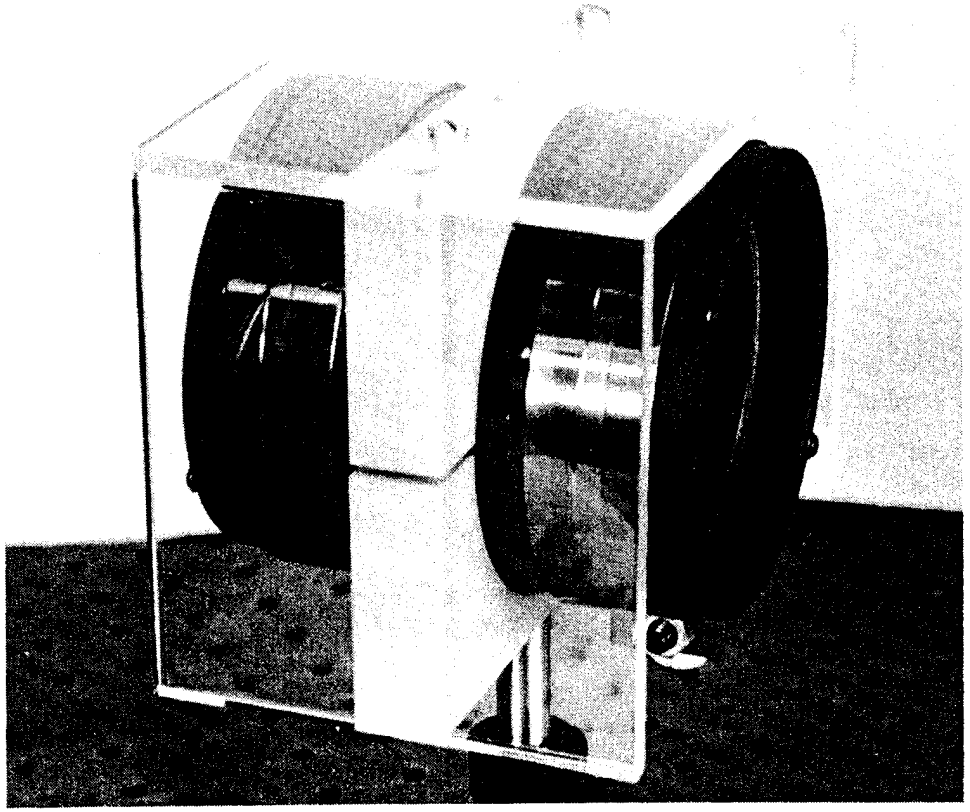
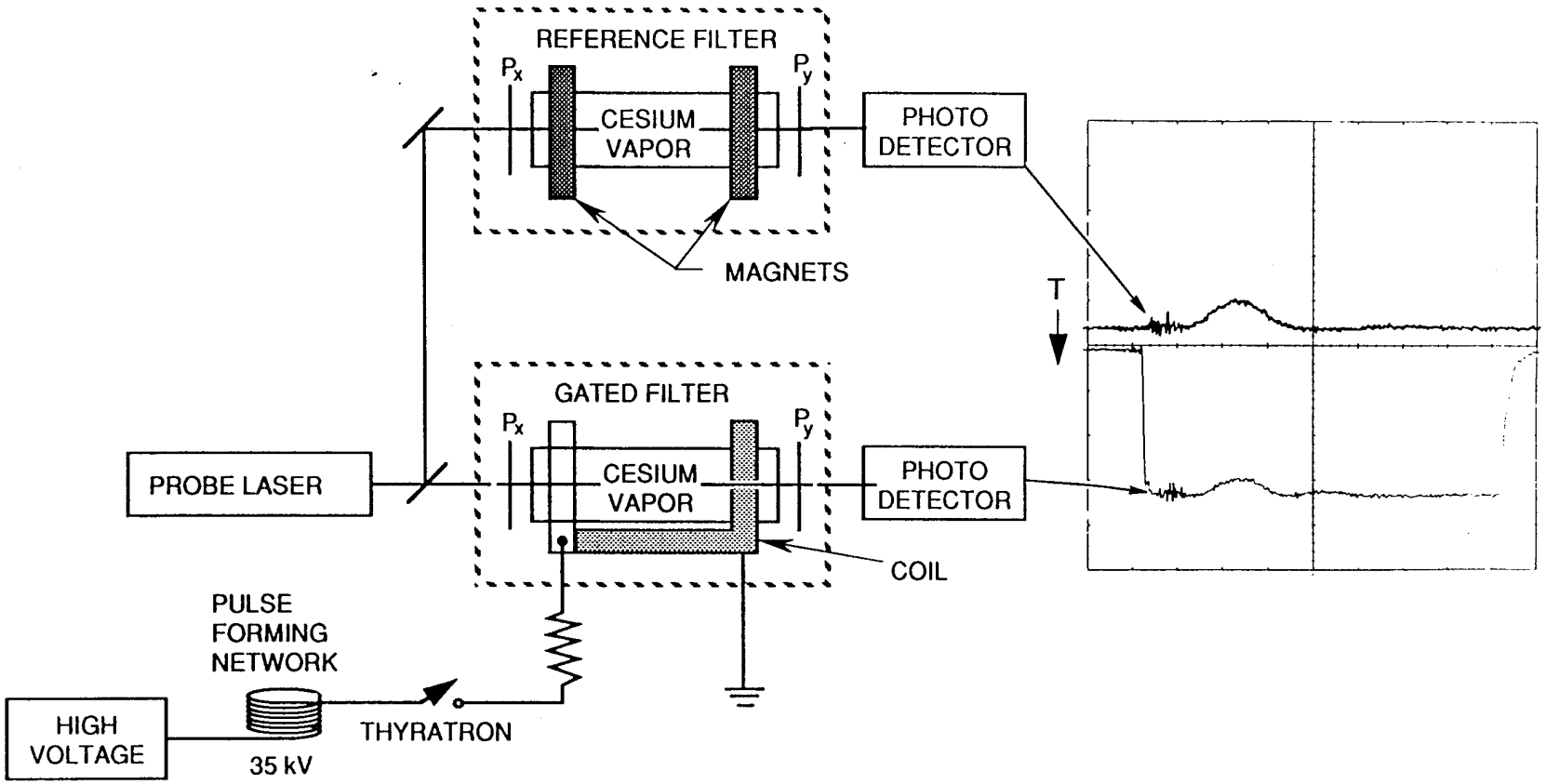
GATED CESIUM FARADAY FILTER



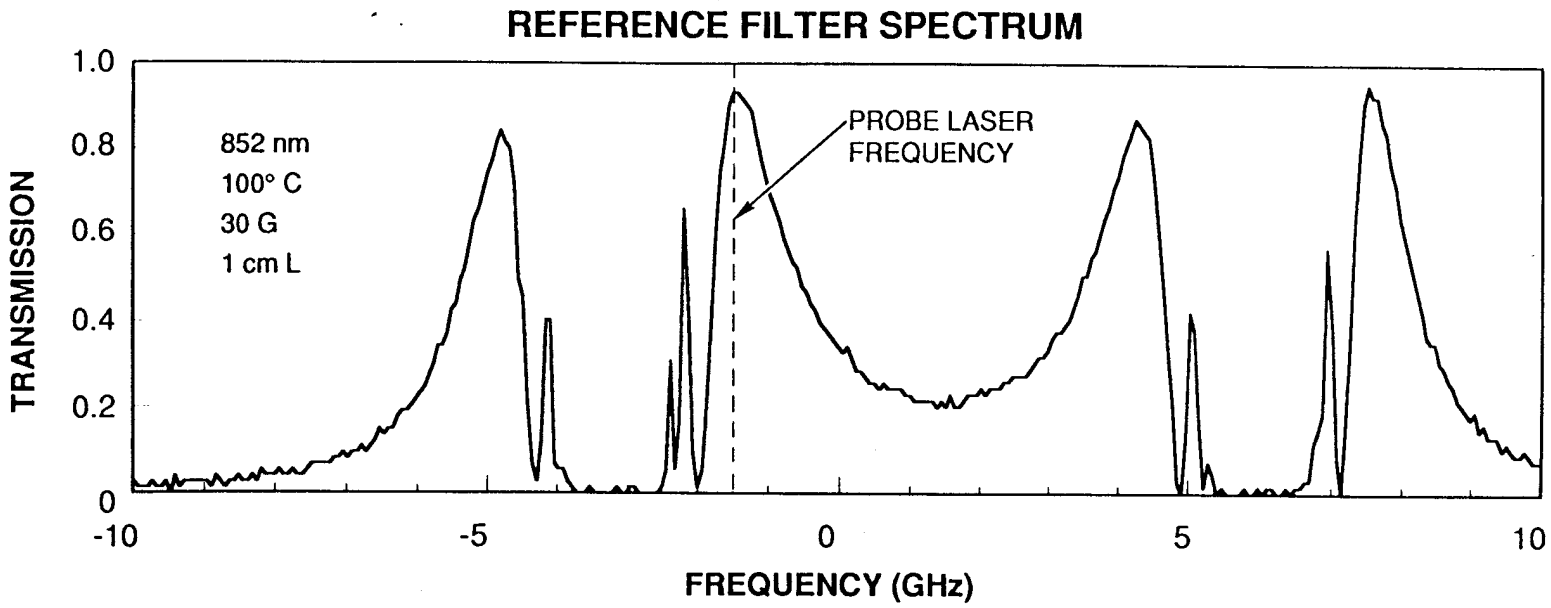
- Ultra-narrow bandpasses at 455, 459, 852 and 894 nm
- Unobscured 1 in. CA at angles up to 30° (2 in. CA at normal incidence)
- Out-of-band transmission (on axis) ~ 10^{-5}
- Open transmission (to polarized light) 32%

GATED FARADAY FILTER TEST SET-UP



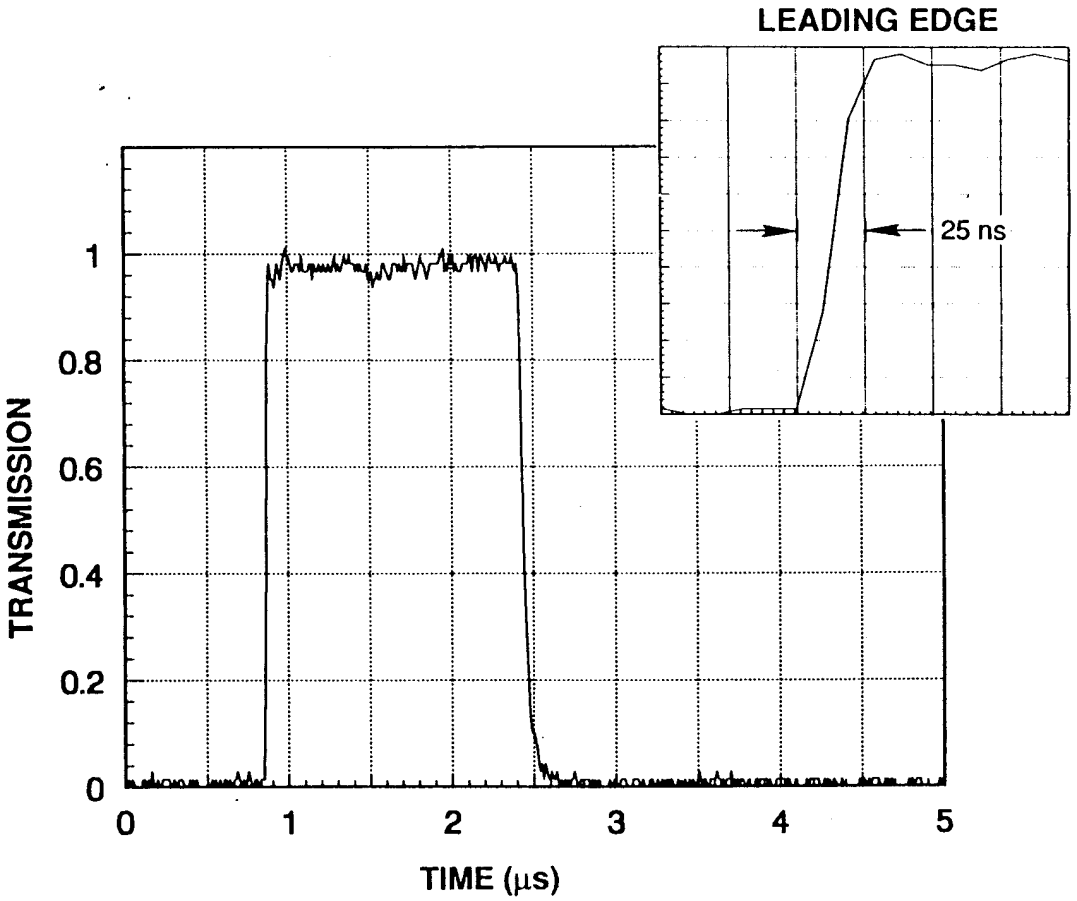
- Gating was demonstrated for the near IR and blue passbands
  - NIR: Single mode diode laser at 852 nm
  - Blue: Single frequency dye laser at 455 nm
- Laser frequency stability was ascertained from reference filter transmission

NIR GATED FARADAY FILTER TEST CONDITIONS



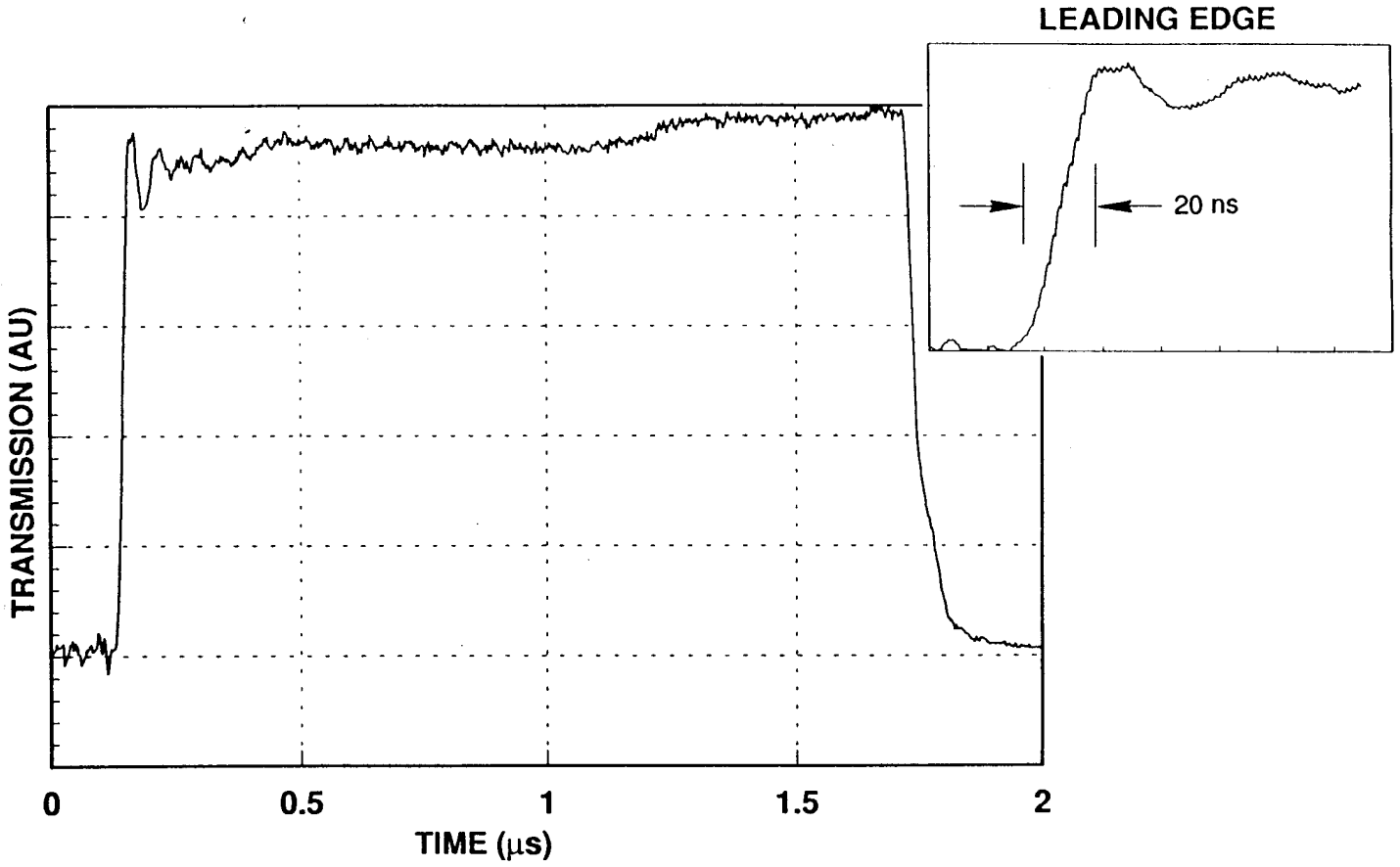
- Developmental testing is easier at 852 nm
  - Single mode diode laser probe
  - Lower temperature/field operating point
- Gated blue filter testing continues at NADC
  - Single frequency blue dye laser

GATED NIR FARADAY FILTER TRANSMISSION



- Transmission with respect to peak passband transmission
- The sharp 20 ns risetime can be used to discriminate against nearby scattering

GATED BLUE FARADAY FILTER TRANSMISSION



- Replicates NIR result
- Absolute transmission measurements are in progress
- A faint blue glow, produced at high temperatures and fields, was observed and is under investigation (RF discharge?)

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CONCLUSION

- The blue Cs Faraday atomic line filter was previously shown to provide ultra narrow, high transmission bandpasses with high background rejection
- The filter transmission may be modulated by varying the field, providing suppression of close range scattering
- The optimal operating vapor temperature of 200°C minimizes the field requirement while avoiding the collisionally broadened regime
- Gating tests at 852 nm and 455 nm demonstrated rapid 20-25 ns transmission risetimes in a 2" aperture, wide field-of-view filter