ULTRA-SLOW AND STOPPED LIGHT[1] IN A RARE-EARTH-DOPED CRYSTAL

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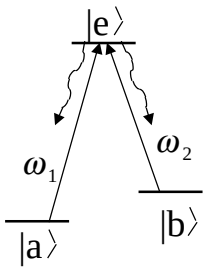
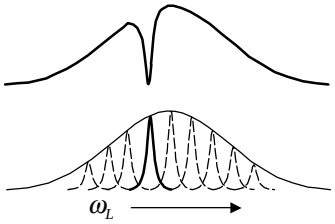
FUTURE PROJECTIONS:
MAT SELLARS - A.N.U.



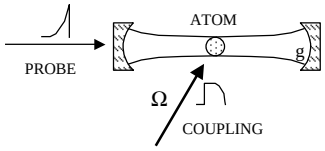


STOPPED LIGHT FOR QUANTUM STORAGE

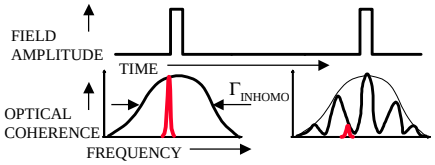
2

LIGHT STORAGE TECHNIQUES

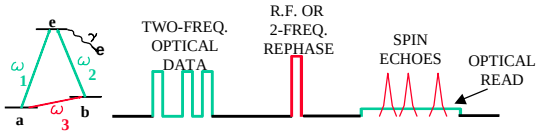
CAVITY QED AND TIME SYMMETRIC PULSES
- THEORETICALLY 100 % FIDELITY
- DIFFICULT TO IMPLEMENT EXPERIMENTALLY
- FIDELITY IN PRACTICE WILL BE LOW



PHOTON ECHO
- ATOMS LEFT IN EXCITED STATE
- OPTICAL FID SIGNAL = LOSS



RAMAN EXCITED SPIN ECHO
- NO OPTICAL FID
- 50 % OF ATOMS STILL EXCITED



SLOW AND STOPPED LIGHT
- THEORETICALLY 100 % EFFICIENT
- EASY TO IMPLEMENT
- > 99 % ALREADY STORED IN SLOW LIGHT
- LOSSES IN STOPPING TEHCNIQUE LESS CRITICAL

3

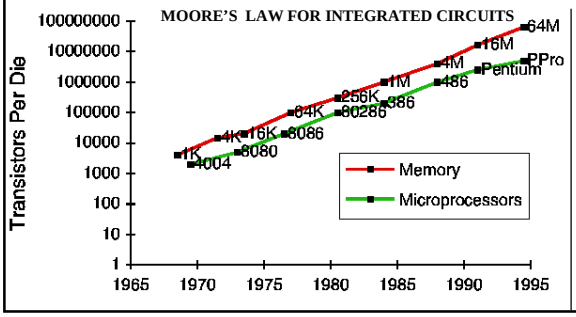
MOTIVATION: QUANTUM COMPUTING

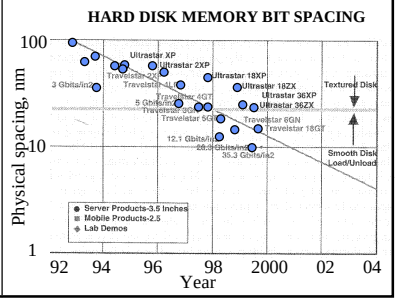
MOORE'S LAW

- NUMBER OF TRANSISTORS DOUBLES IN ~ 18 MONTHS
- QUANTUM SIZE LIMITS APPROACHED
  - BITS/ATOM INSTEAD OF ATOMS/BIT
- MEMORY WILL REACH LIMIT FIRST
  - ~10YRS -- REFRIGERATED HARD DRIVES
- **NEED TO MAINTAIN TECHNICAL SUPERIORITY**

SOLUTION

- WHAT CAN A FEW ATOMS DO? -- SCALE UP
- EXPONENTIAL SPEEDUP
  - FACTORING, FFT
- QUADRATIC SPEEDUP (LIKE FFT VS. CONVENTIONAL F.T.)
  - UNSORTED SEARCH, COMPUTATIONAL FLUID DIYNAMICS





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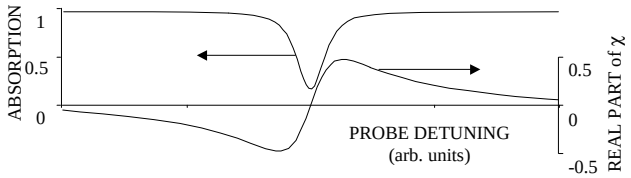
SLOW LIGHT BASICS

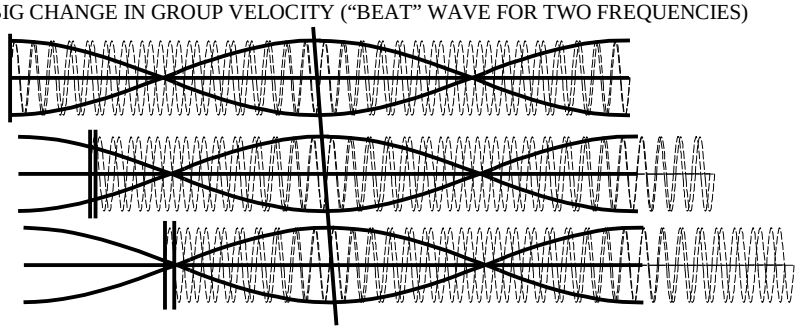
ANY MATERIAL WITH NARROW TRANSPARENCY WINDOW

- GROUP VELOCITY DEPENDS ON SLOPE
- INFORMATION TRANSFER SPEED



SMALL CHANGE IN DIFFERENTIAL PHASE VELOCITY

BIG CHANGE IN GROUP VELOCITY ("BEAT" WAVE FOR TWO FREQUENCIES)



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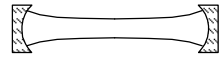
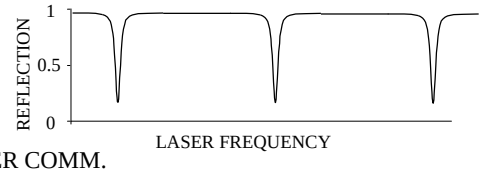
SLOW LIGHT MATERIALS

ANY MATERIAL WITH NARROW TRANSPARENCY WINDOW
- FABRY-PEROT CAVITY
- SPECTRAL HOLE BURNING MATERIAL

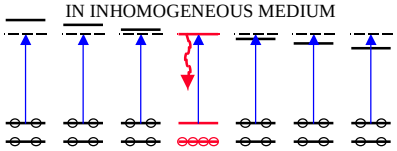


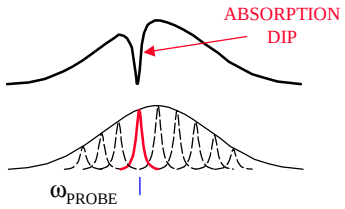
FABRY-PEROT CAVITY



USED FOR TIME DELAY IN FIBER COMM.
- DELAY DEPENDS ON INVERSE LINEWIDTH

SPECTRAL HOLE BURNING
IN INHOMOGENEOUS MEDIUM





SLOWEST PROJECTED LIGHT SPEED IN SOLID: Equall, Sun, Cone, Macfarlane, PRL 72, 2179 (1994)
OPTICAL HOLE BURNING IN Eu:YSO, WIDTH=100Hz, OPTICAL DENSITY=1.4, LENGTH=1cm
PROJ. LIGHT SPEED ~4 m/s, DELAY ~2.5msec
EXPERIMENT PERFORMED (SELLARS, MANSON) ~ 10's OF m/s

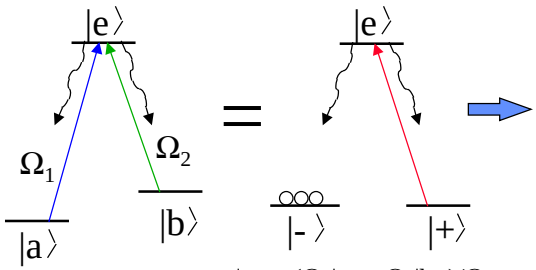
6

THE DARK RESONANCE (CONTROLLABLE TRANSPARENCY)

OTHER NAMES
- COHERENT POPULATION TRAPPING
- ELECTROMAGNETICALLY INDUCED TRANSPARENCY
- RESONANCE RAMAN

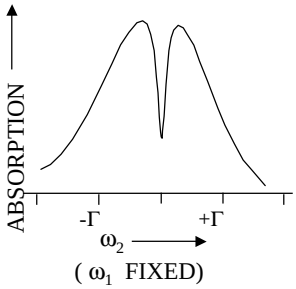
APPLICATIONS:
- LASING WITHOUT INVERSION
- PHASONIUM

EXAMPLE: CPT
- DISSIPATION CREATES COHERENCES
- DARK STATE $|- >= (|a> - |b>)$



$|-> = (\Omega_2|a> - \Omega_1|b>)/\Omega$
$|+> = (\Omega_1|a> + \Omega_2|b>)/\Omega$

TRANSPARENCY WIDTH DETERMINED BY COUPLING INTENSITY (Ω_1)



(ω_1 FIXED)

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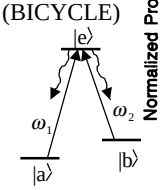
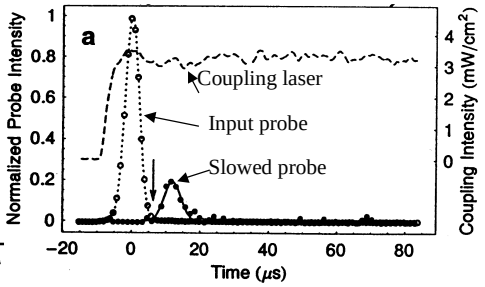
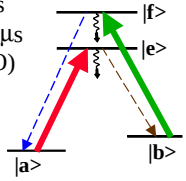
FIRST ULTRA-SLOW LIGHT OBSERVATIONS

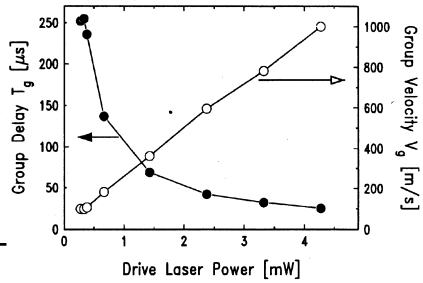
ULTRA-COLD ATOMIC VAPOR
- ALMOST BOSE CONDENSATE
- NO DOPPLER, CLEAN Λ SYSTEM
- LIGHT SPEED ~ 10 m/s (BICYCLE)





HOT ATOMIC VAPOR (> ROOM T)
- DOUBLE Λ SYSTEM
- DETECT WITH MODULATION TECH.
- LIGHT SPEED ~ 100 m/s
- LARGE DELAYS ~ 200 μs (SINGLE PHOTON NLO)





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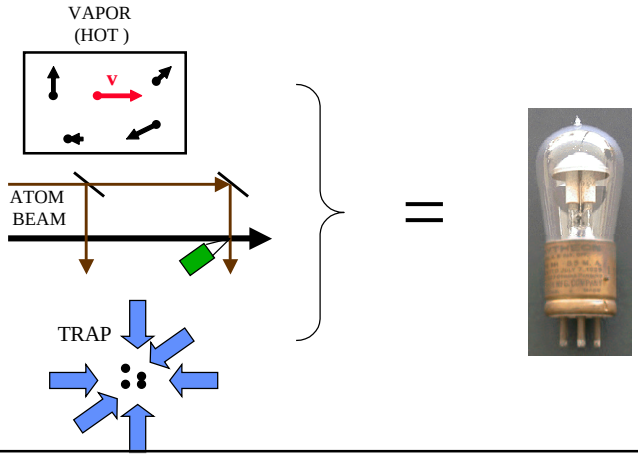
SLOW& STOPPED LIGHT IMPLEMENTATION VACUUM TUBES VS. SOLID STATE

VAPOR CELLS, ATOMIC BEAMS, ATOM TRAPS, BOSE CONDENSATE
- WORK
- DIFFICULT TO MASS PRODUCE OR SCALE UP

WANT SOLID STATE



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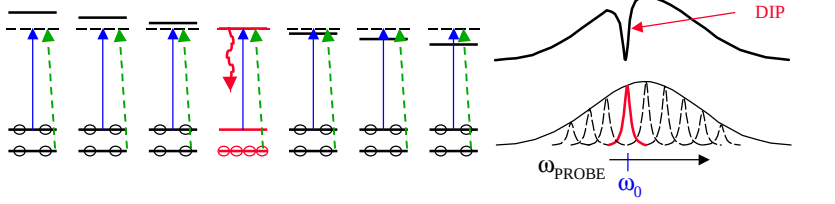
DARK RESONANCES IN SOLIDS: RARE-EARTH DOPED CRYSTALS

PROPERTIES SIMILAR TO HOT VAPORS
- OPTICAL INHOMO. BROADENING ~GHz
- LONG-LIVED GROUND-STATE LIFETIMES:
  - COHERENCE T_2~msec, POPULATION T_1~sec,
- RAMAN TRANSITIONS ALLOWED

PROPERTIES SIMILAR TO ULTRA-COLD VAPORS
- NO ATOMIC MOTION

DOPED CRYSTALS ARE EXAMPLES OF SPECTRAL HOLE BURNING MATERIALS

PHYSICS OF PERSISTENT SPECTRAL HOLE BURNING



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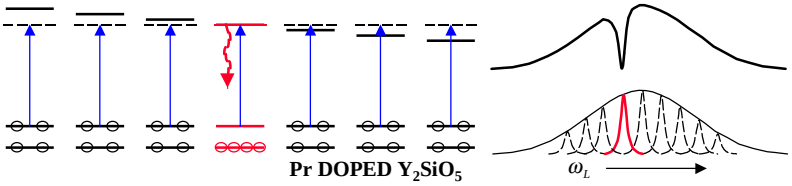
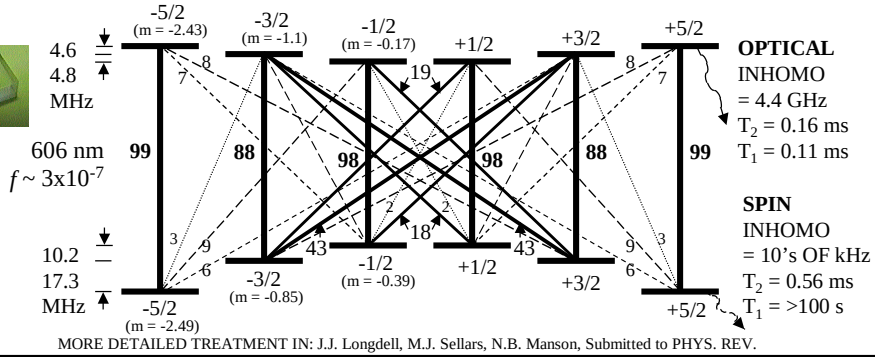
OPTICALLY ADDRESSED SPINS IN SOLIDS EXAMPLE -- Pr DOPED Y_2SiO_5



Pr DOPED Y_2SiO_5

0.05% Pr (SITE 1), C_1 SYMMETRY -- NO SPIN-ORBIT

GROUND AND EXCITED STATE QUANTIZATION AXES DIFFERENT ORIENTATION



MORE DETAILED TREATMENT IN: J.J. Longdell, M.J. Sellars, N.B. Manson, Submitted to PHYS. REV.

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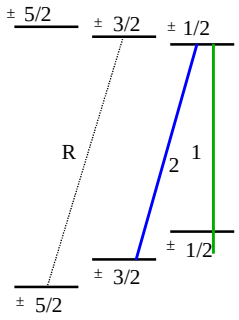
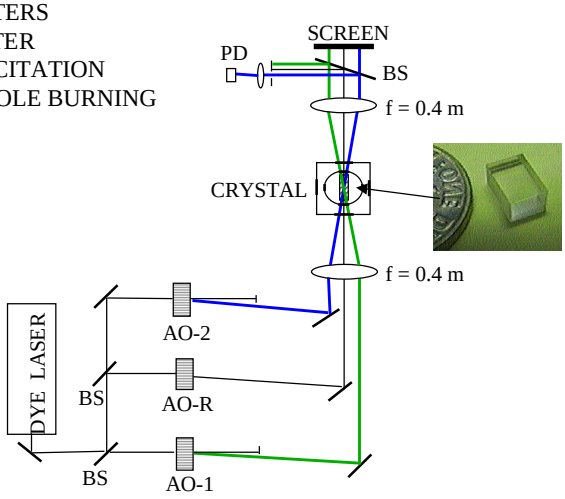
EXPERIMENTAL SETUP TO OBSERVE SLOW LIGHT IN SOLIDS

USE ACOUSTO-OPTIC SHIFTERS
- CORRELATED LASER JITTER

NEED REPUMP FOR CW EXCITATION
- SUPPRESS PERSISTENT HOLE BURNING (ANTI-HOLE)

SIMPLIFIED LEVEL DIAGRAM





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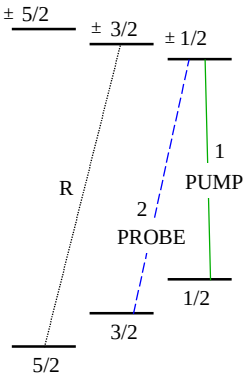
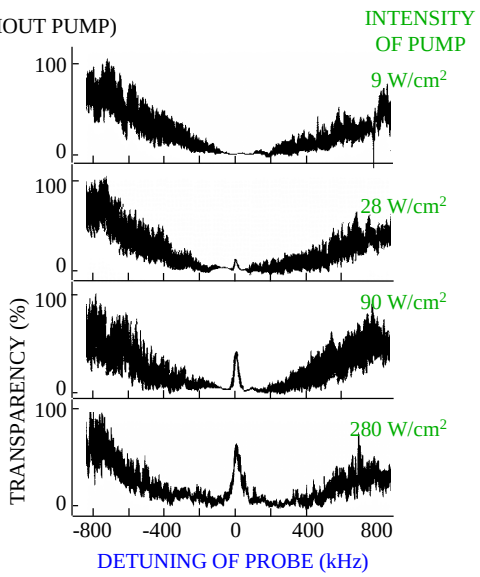
DARK RESONANCE EXCITATION IN Pr:YSO

PROBE ABSORPTION > 95 % (WITHOUT PUMP)
TEMPERATURE = 2 ºK
LASER JITTER = 1 MHz
MAX PUMP RABI = 0.14 MHz
PROBE = 9 W/cm^2 = 25 kHz
REPUMP = 16 W/cm^2



LEVEL DIAGRAM



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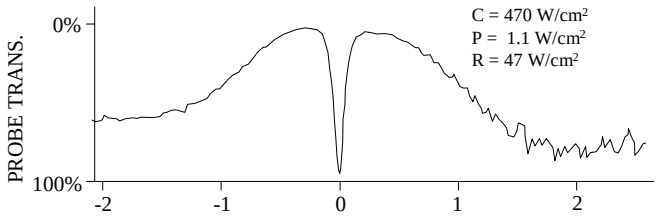
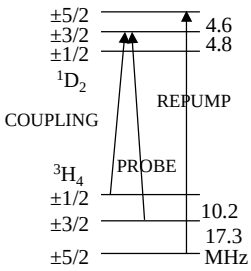
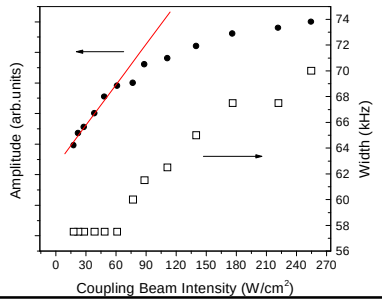
NEAR 100% EFFICIENT CPT IN Pr: YSO

CRYSTAL TEMPERATURE = ~5 K
OPTICAL ABSORPTION ~ 95%
CRYSTAL LENGTH ~ 3 mm
LINEWIDTH ~ 100 kHz



SIMPLIFIED LEVEL DIAGRAM





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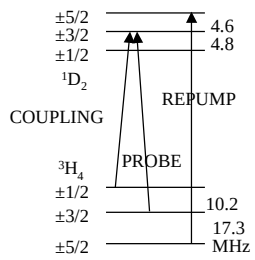
DARK RESONANCE EXCITATION IN Pr:YSO

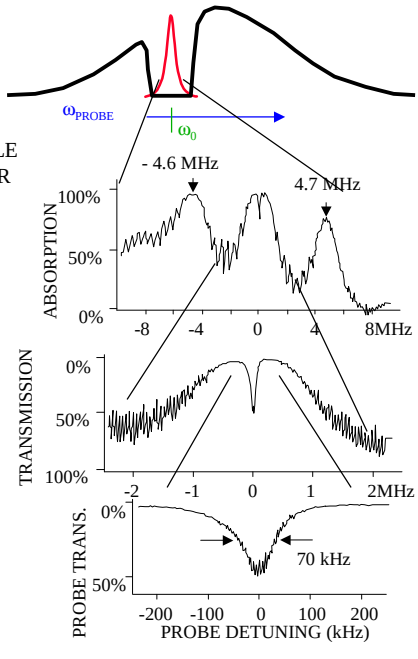
<u>WITHOUT REPUMP</u>
INTENSE PUMP BURNS BROAD HOLE
- PROBE ABSORPTION = 0
- HOLE LIFETIME = T_1 ~ 100 sec

<u>APPLY REPUMP</u>
- EMPTY 5/2 LEVEL -- CREATE ANTI-HOLE
- PROBE ABSORPTION ∝ REPUMP POWER
- ANTI-HOLE WIDTH = LASER JITTER
- 3 ANTI-HOLES -- 3 EXCITED STATES

<u>RESULT</u>
- EFFECTIVE INHOMOGENEOUS WIDTH IS ~ 1 MHz INSTEAD OF 4.4 GHz
- EFFICIENT EIT
- PROJECTED LIGHT SPEED ~ km/sec

Pr:YSO LEVEL DIAGRAM





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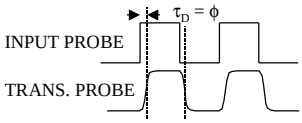
OBSERVATION OF SLOW LIGHT IN SOLIDS

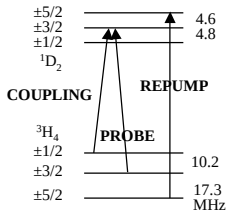
MEASURED LIGHT SPEED
- LIGHT SPEED **< 50 m/s**
  - MODULATED PROBE TECH.
  - f_m = 2-20 kHz

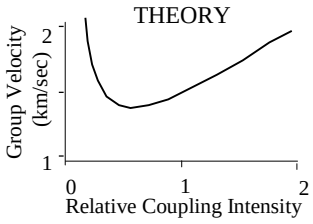
COMPARABLE TO VAPOR:
- **SOUND SPEED ~ 1000 m/s**
- DIS-AGREES WITH THEORY

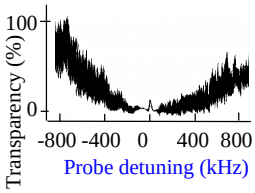


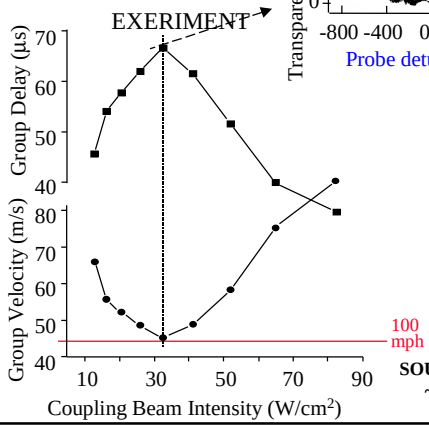
MODULATED PROBE TECHNIQUE
- PERIODIC SIGNAL, TIME DELAY = PHASE

LEVEL DIAGRAM









SOUND SPEED ~ 1000 m/s

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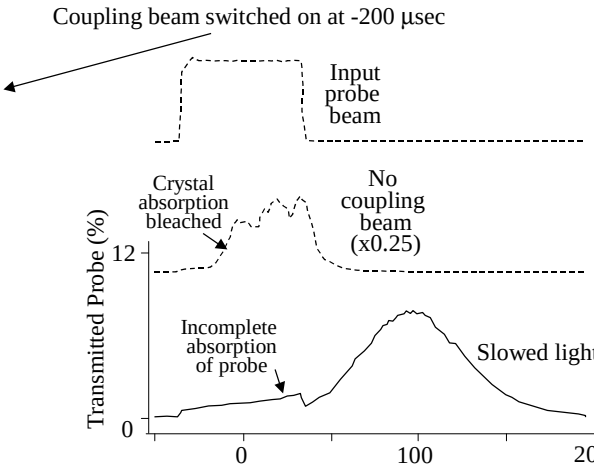
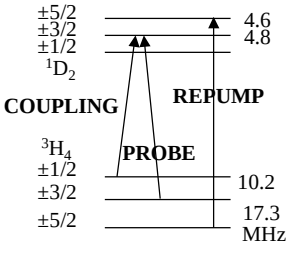
SLOW LIGHT PULSES IN Pr:YSO

LARGE MEASURED DELAYS
- UP TO 100 µsec = 33 m/s (70 mph)
- PROBE INTENSITY HIGHER
  - OVERCOME COUPLING BEAM SCATTER





LEVEL DIAGRAM

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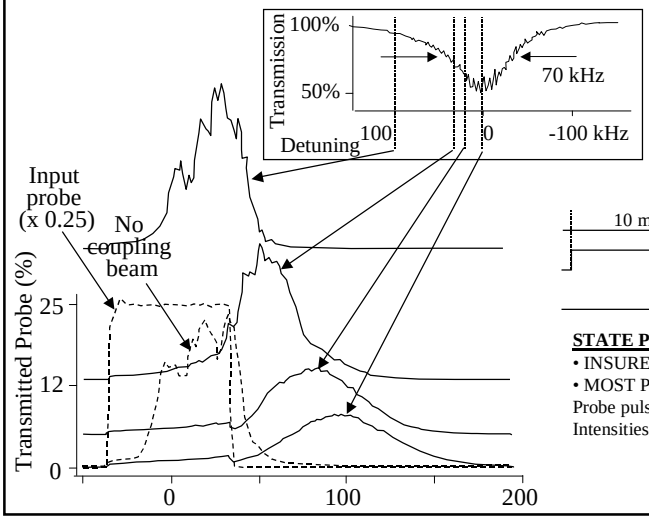
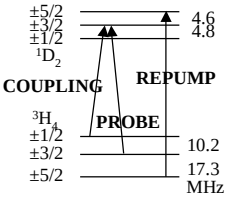
PULSE DELAYS VS DETUNING IN Pr:YSO

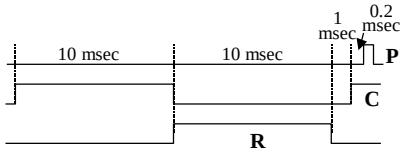
LARGE MEASURED DELAYS
- UP TO 100 μsec = 33 m/s (70 mph)
- AGREES WITH MODULATION TECH.
- TIED TO DARK RESONANCE

DELAY EXISTS WITHOUT COUPLING
- STRONGER PROBE THAN CW CASE





LEVEL DIAGRAM



STATE PREPARATION PULSE SEQUENCE
- INSURES ±1/2 LEVEL EMPTY: COUPLING
- MOST POPULATION IN ±3/2: PROBE

Probe pulse width: 70 μsec.
Intensities: C = 77 W/cm², P = 5.5 W/cm², R = 120 W/cm².

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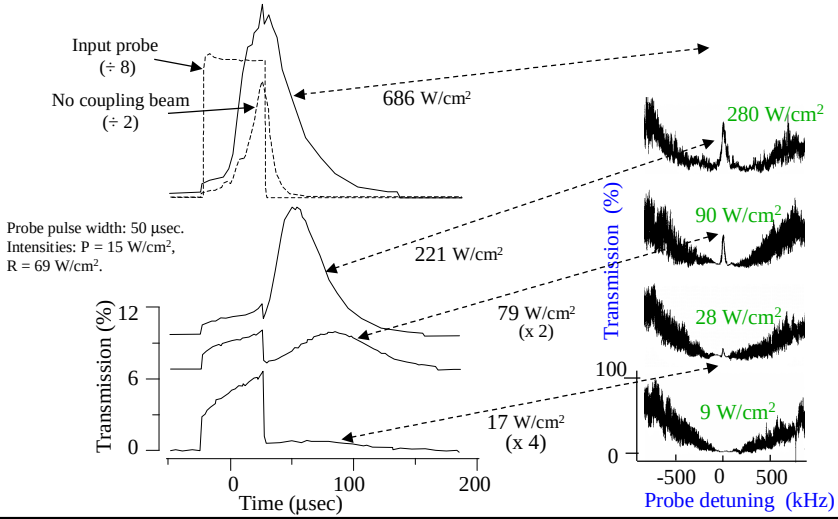
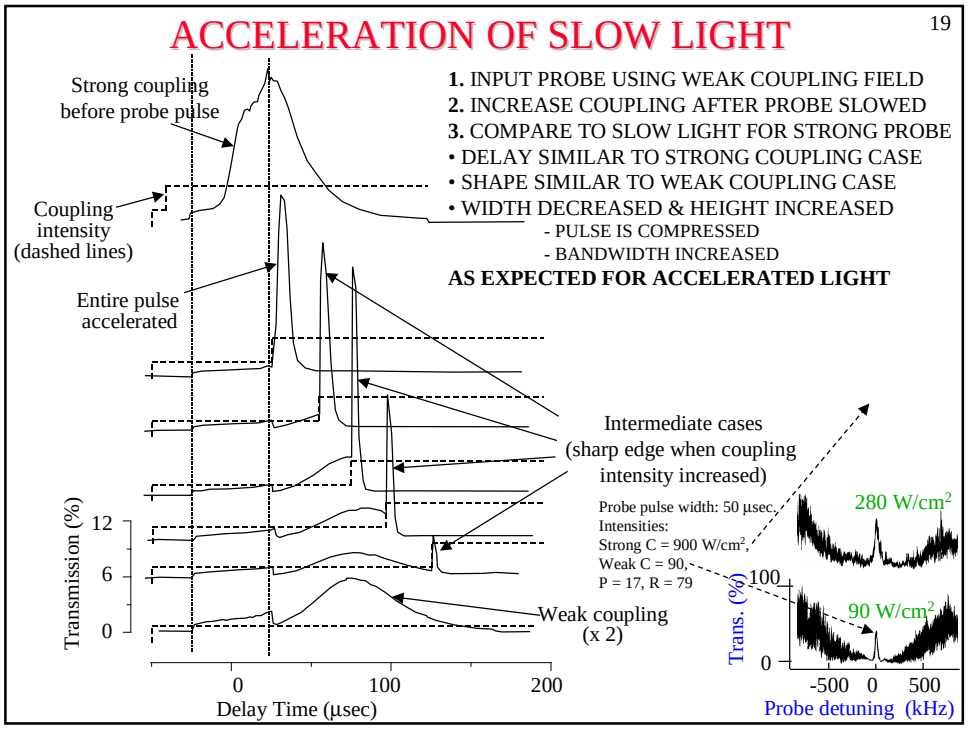
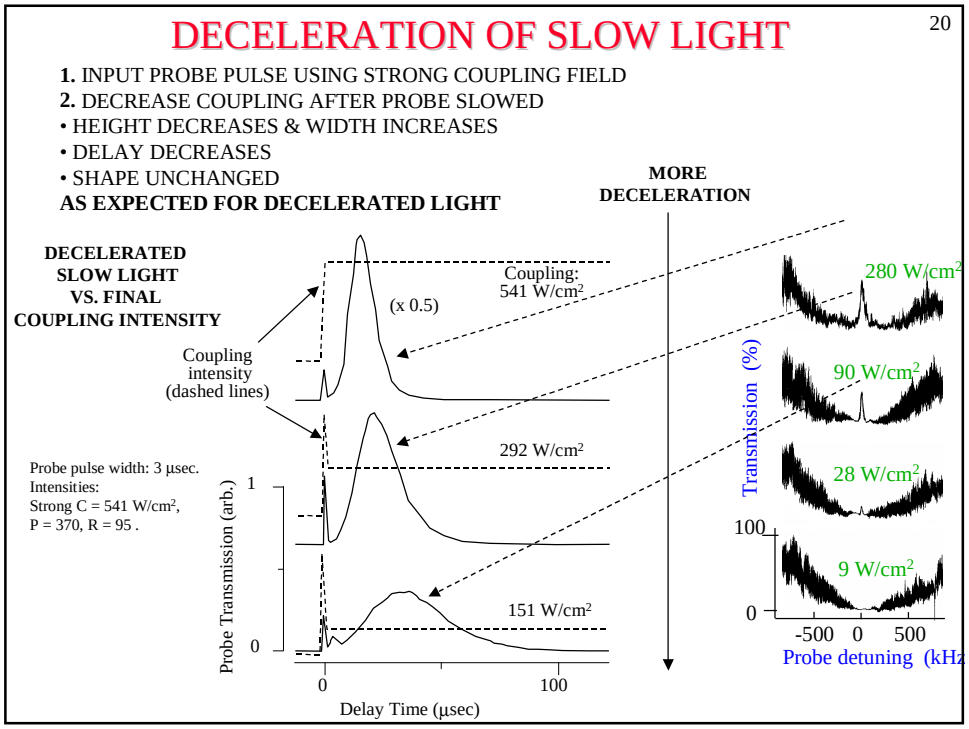
GROUP DELAY VS. COUPLING INTENSITY

INCREASED COUPLING POWER REDUCES DELAYS -- SPEEDS UP LIGHT
- EIT POWER-BROADENS
- OUTPUT PULSE MORE LIKE INPUT
- FOURIER TRANSFORM OF EDGES LIE WITHIN EIT BANDWIDTH

COMPLEX TRANSMITTED PULSE SHAPE
- FIRST PART DUE TO UNABSORBED PROBE BEAM
- ABSORPTION ~ 95% AT REPUMP INTENSITY USED

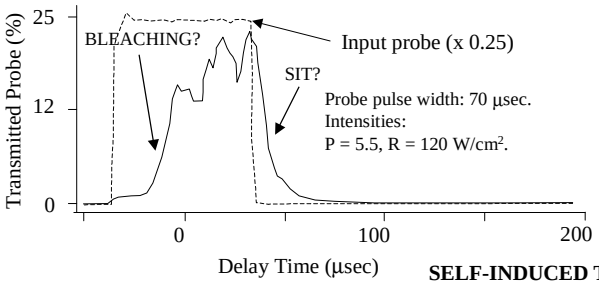



ACCELERATION OF SLOW LIGHT
19
Strong coupling before probe pulse
Coupling intensity (dashed lines)
Entire pulse accelerated
1. INPUT PROBE USING WEAK COUPLING FIELD
2. INCREASE COUPLING AFTER PROBE SLOWED
3. COMPARE TO SLOW LIGHT FOR STRONG PROBE
• DELAY SIMILAR TO STRONG COUPLING CASE
• SHAPE SIMILAR TO WEAK COUPLING CASE
• WIDTH DECREASED & HEIGHT INCREASED
- PULSE IS COMPRESSED
- BANDWIDTH INCREASED
AS EXPECTED FOR ACCELERATED LIGHT
Intermediate cases (sharp edge when coupling intensity increased)
Weak coupling (x 2)
Transmission (%)
12
6
0
0
100
200
Delay Time (μsec)
Probe pulse width: 50 μsec.
Intensities:
Strong C = 900 W/cm2,
Weak C = 90,
P = 17, R = 79
280 W/cm2
90 W/cm2
Trans. (%)
100
0
-500 0 500
Probe detuning (kHz)

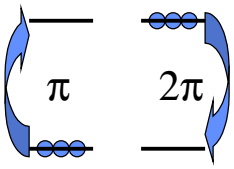

DECELERATION OF SLOW LIGHT
20
1. INPUT PROBE PULSE USING STRONG COUPLING FIELD
2. DECREASE COUPLING AFTER PROBE SLOWED
• HEIGHT DECREASES & WIDTH INCREASES
• DELAY DECREASES
• SHAPE UNCHANGED
AS EXPECTED FOR DECELERATED LIGHT
MORE DECELERATION
DECELERATED SLOW LIGHT VS. FINAL COUPLING INTENSITY
Coupling intensity (dashed lines)
Coupling: 541 W/cm2
(x 0.5)
292 W/cm2
151 W/cm2
Probe pulse width: 3 μsec.
Intensities:
Strong C = 541 W/cm2,
P = 370, R = 95 .
Probe Transmission (arb.)
1
0
0
100
Delay Time (μsec)
280 W/cm2
90 W/cm2
28 W/cm2
9 W/cm2
Transmission (%)
100
0
-500 0 500
Probe detuning (kHz

21

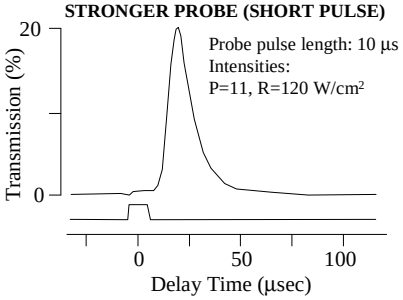
SIT-LIKE DELAYS IN Pr:YSO



2π RABI FLOPS GIVE TRANSPARENCY



STRONGER PROBE (SHORT PULSE)



SELF-INDUCED TRANSPARENCY (SIT)

- DELAY WITHOUT COUPLING LASER
- SATURATION CREATES TRANSPARENCY
- PULSE AREA ~ 2 π
- COMPLETE RABI FLOP -- NO ABSORPTION
- USED TO SLOW LIGHT (BEFORE EIT)

CURRENT & PRIOR ('99) EXPERIMENTS

G. Zumofen, F.R. Graf, A. Renn, U.P. Wild, *J. of Lumin.* 83-84 (1999) 379.

- MEASURED DELAYS ~ 20 µsec
- GROUP VELOCITY **150 m/s**
- LASER PHASE COHERENCE < 1 µsec ??
- GET FULL PULSE-WIDTH DELAYS

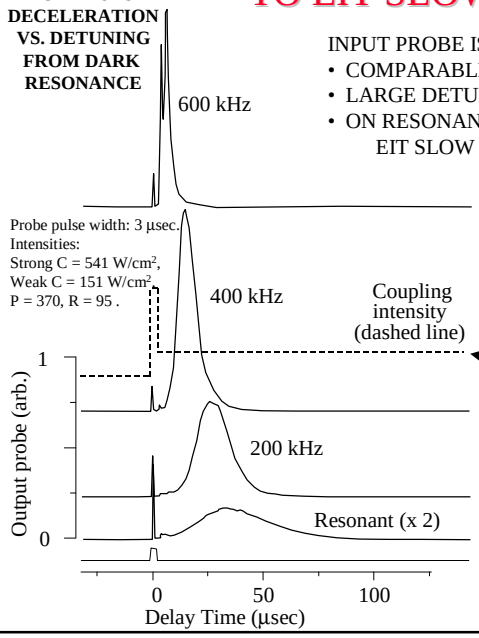
LIMITATIONS OF SIT

- DELAY DEPENDS ON PROBE INTENSITY
- SHAPE FIXED (SECH)

22

CONVERSION OF SIT SOLITON TO EIT SLOW LIGHT

LIGHT PULSE DECELERATION VS. DETUNING FROM DARK RESONANCE

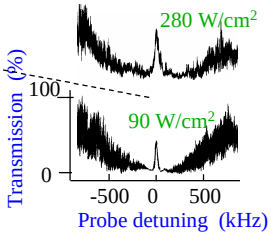


INPUT PROBE IS VERY STRONG

- COMPARABLE TO COUPLING
- LARGE DETUNING -- SIT-LIKE SLOW LIGHT (SOLITON)
- ON RESONANCE -- SIT SOLITON CONVERTED TO EIT SLOW LIGHT WHEN PROBE IS SWITCHED OFF

COMPLEX PULSE SHAPE

- DETECTOR SHUTTERED WHEN STRONG PROBE IS ON



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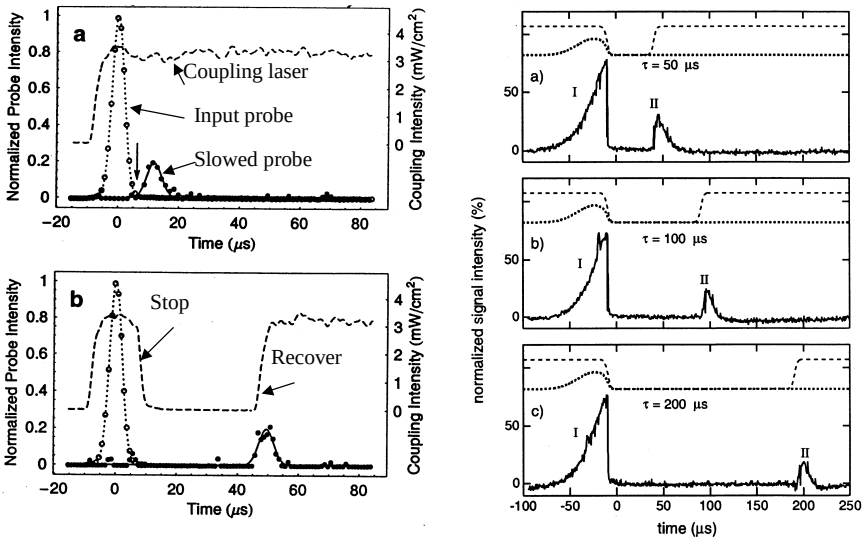
STOPPED LIGHT IN VAPOR

ULTRA COLD VAPOR **HOT VAPOR**



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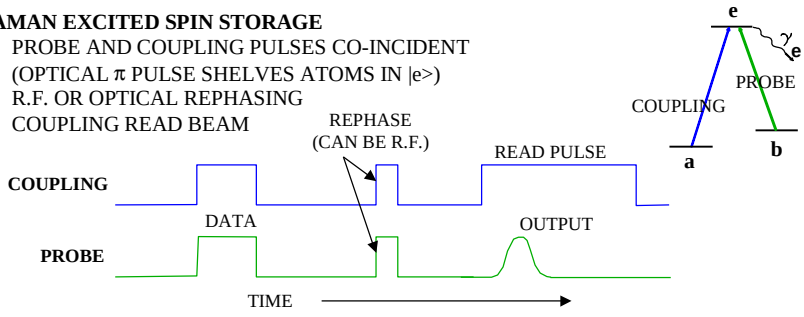
RAMAN SPIN ECHO VS STOPPED LIGHT

SOLIDS HAVE INHOMOGENEOUS BROADENED SPIN TRANSITIONS

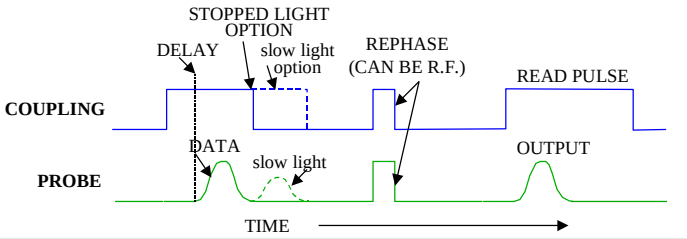
RAMAN EXCITED SPIN STORAGE

- PROBE AND COUPLING PULSES CO-INCIDENT (OPTICAL π PULSE SHELVES ATOMS IN |e>)
- R.F. OR OPTICAL REPHASING
- COUPLING READ BEAM



SLOW AND STOPPED LIGHT

- COUPLING PULSE PRECEEDS PROBE (ADIABATIC PASSAGE, NO EXCITED STATE)



OBSERVATION OF STOPPED LIGHT

25

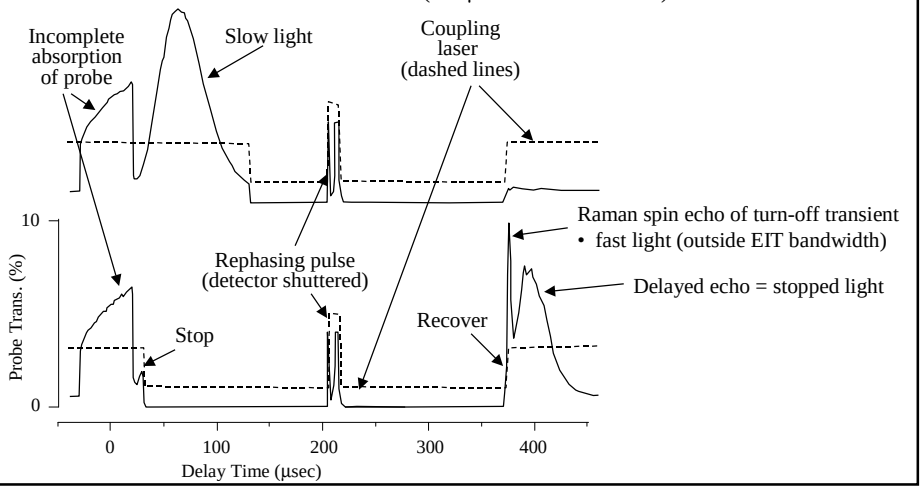
1. WAIT UNTIL SLOWED PROBE PULSE IS INSIDE CRYSTAL
2. TURN OFF COUPLING FIELD

LIGHT IS STOPPED OR STORED

3. RESTORE COUPLING FIELD TO RECOVER SLOW LIGHT

FOR SOLID:

- ALSO NEED REPHASING PULSE
- SIGNAL DECAYS WITH STORAGE TIME (500 μsec SPIN LIFETIME)



ACCELERATION OF STOPPED LIGHT

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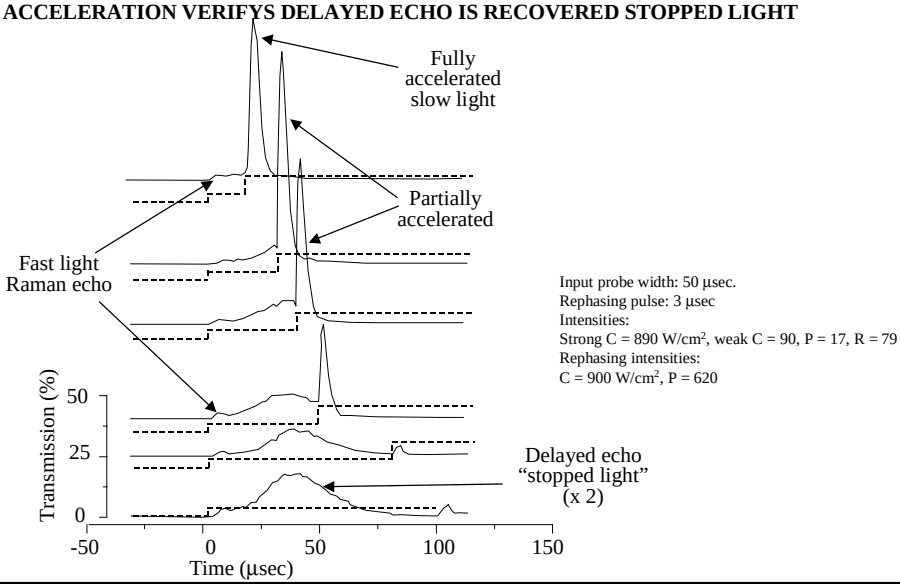
VERIFY DELAYED ECHO IS SLOW LIGHT = RECOVERED STOPPED LIGHT

1. READOUT STORED LIGHT WITH WEAK COUPLING FIELD
2. INCREASE COUPLING FIELD INTENSITY AFTER DELAY

ACCELERATION VERIFYS DELAYED ECHO IS RECOVERED STOPPED LIGHT



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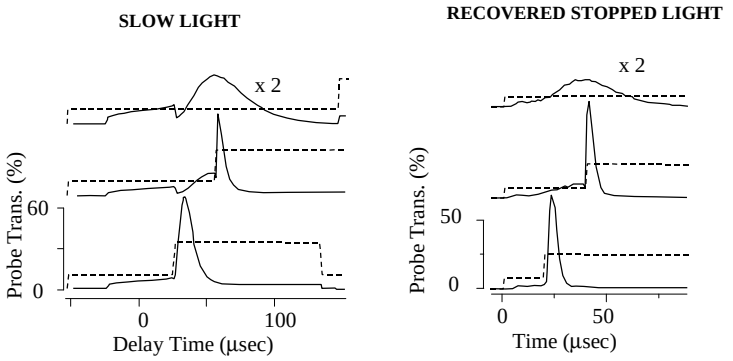
COMPARE ACCELERATED SLOW AND STOPPED LIGHT

QUALITATIVELY SAME CHARACTERISTICS
- DELAYED ECHO IS RECOVERED STOPPED LIGHT
- NOT ECHO OF EARLIER TRANSIENT



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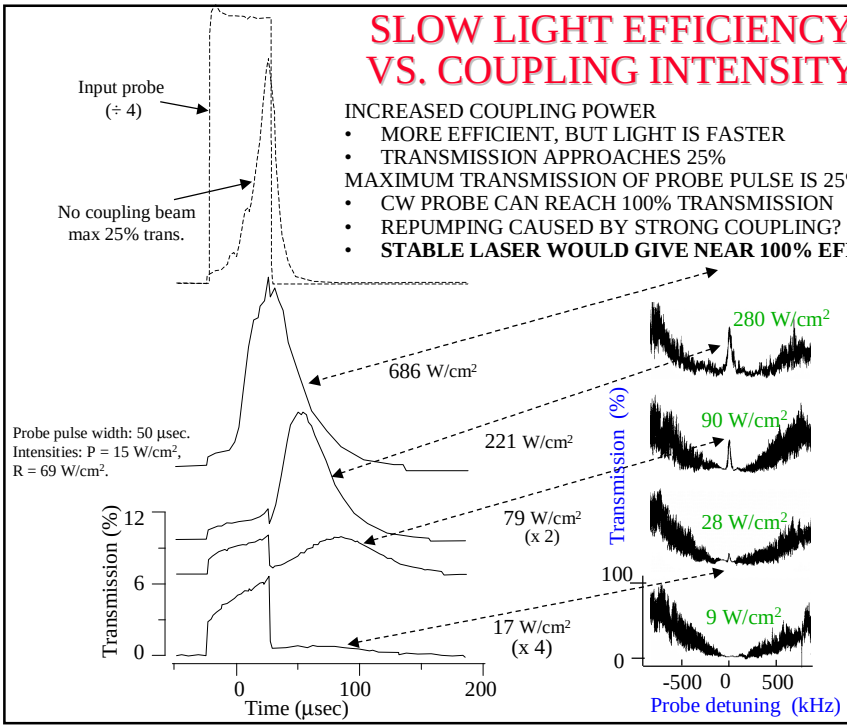
SLOW LIGHT EFFICIENCY VS. COUPLING INTENSITY

INCREASED COUPLING POWER
- MORE EFFICIENT, BUT LIGHT IS FASTER
- TRANSMISSION APPROACHES 25%

MAXIMUM TRANSMISSION OF PROBE PULSE IS 25%
- CW PROBE CAN REACH 100% TRANSMISSION
- REPUMPING CAUSED BY STRONG COUPLING?
- **STABLE LASER WOULD GIVE NEAR 100% EFFICIENCY**

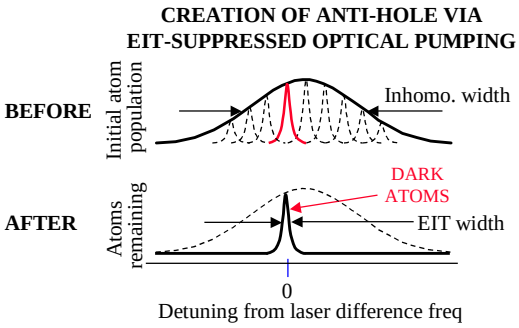


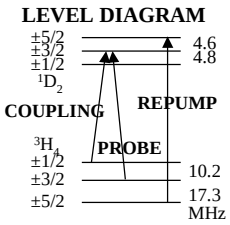
29

SPIN ANTI-HOLEBURNING

OPTICAL PUMPING & HOLEBURNING SUPPRESSED NEAR EIT RESONANCE
- FIRST PROBE PULSE BLEACHES ABSORBING ATOMS
- ANTI-HOLE IS FORMED
- SECOND PROBE BEAM HAS HIGHER TRANSMISSION
- SIMILAR LIGHT SPEED

ANTI-HOLE BURNING ALSO EXPLAINS ANAMOLOUSLY SLOW LIGHT VELOCITY
- EFFECTIVE EIT WIDTH IS NOT FULL SPIN INHOMOGENEOUS WIDTH
- LIGHT SPEED IS NOT INVERSE OF INHOMO. BANDWIDTH



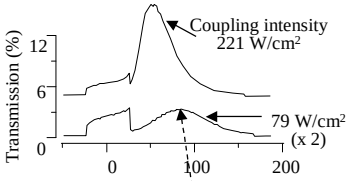


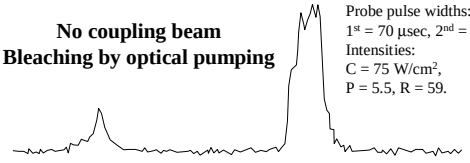
30

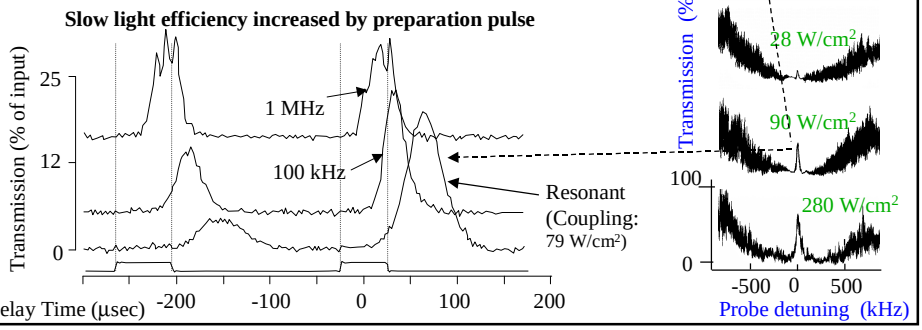
ENHANCE SLOW LIGHT EFFICIENCY FOR WEAK COUPLING VIA EXTRA PROBE PULSE

USE OPTICAL PUMPING TO SUPPRESS ABSORPTION
- APPLY **PREPARATION** PULSE AT PROBE FREQ.
- SLOW LIGHT EFFICIENCY GREATLY INCREASED
- LIGHT-SPEED EFFECT MINIMAL

EXPECT NEAR 100% EFFICIENCY FOR STABLE LASER







ENHANCED SLOW-LIGHT EFFICIENCY VS. COUPLING INTENSITY

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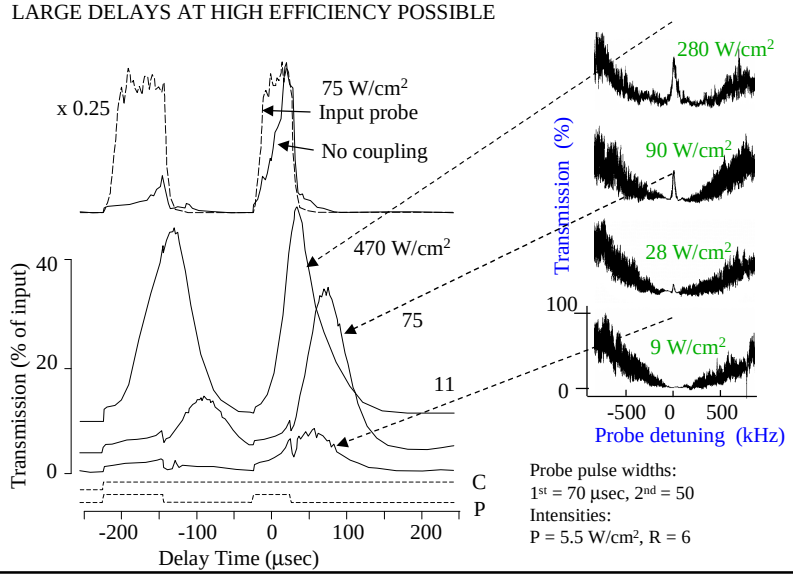
SLOW-LIGHT TRANSMISSION NEAR 100% SEEN IN SINGLE SHOTS
- PREPARATION PULSE ALLOWS HIGH EFFICIENCY AT LOW COUPLING INTENSITY
- LARGE DELAYS AT HIGH EFFICIENCY POSSIBLE



Probe pulse widths:
1st = 70 µsec, 2nd = 50
Intensities:
P = 5.5 W/cm², R = 6

STOPPED LIGHT VS. COUPLING INTENSITY

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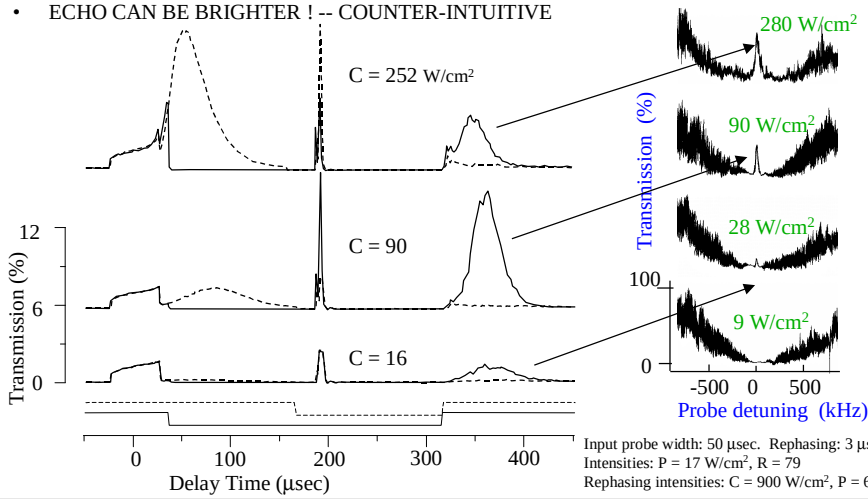
SLOW & STOPPED LIGHT PROPAGATE FASTER AS COUPLING INTENSITY INCREASES
- FURTHER PROOF THAT DELAYED ECHO IS RECOVERED "STOPPED LIGHT"

NOTE FAST LIGHT TRANSIENT DECREASES WITH COUPLING INTENSITY
- LESS PERTURBATION

EFFICIENCY (STOPPED VS SLOWED AMP) IS LARGER FOR LOWER COUPLING INTENSITY
- OPPOSITE OF SLOW LIGHT
- ECHO CAN BE BRIGHTER ! -- COUNTER-INTUITIVE



Input probe width: 50 µsec. Rephasing: 3 µsec
Intensities: P = 17 W/cm², R = 79
Rephasing intensities: C = 900 W/cm², P = 620

33

SPECTRAL MODIFICATION BY π PULSE

STOPPED LIGHT VELOCITY AND AMPLITUDE DIFFERENT FROM SLOWED LIGHT

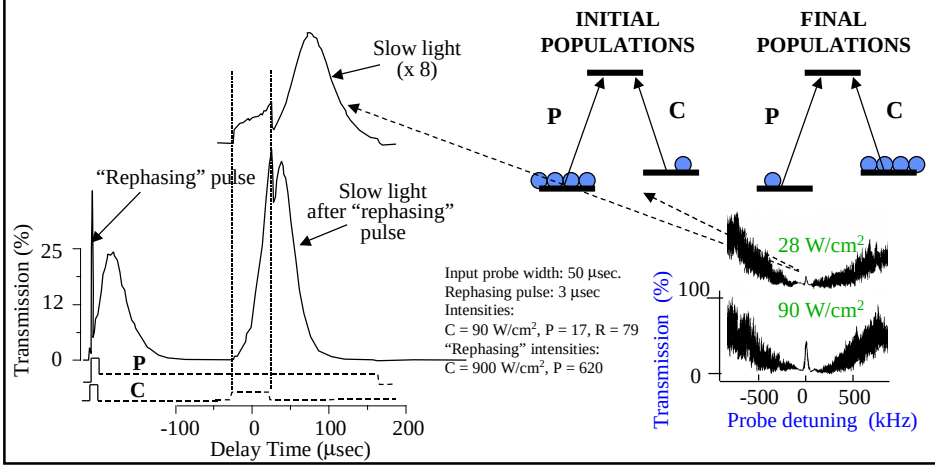
- REPHASING PULSE MODIFIES POPULATIONS
- SWAPS GROUND-STATE POPULATION WHEN IT REVERSES SPIN PHASE

WEAK COUPLING FIELDS

- MORE ABSORPTION INITIALLY, LESS AFTER SWAPPING POPULATIONS

STRONG COUPLING FIELDS

- REPHASING PULSE HAS LESS EFFECT



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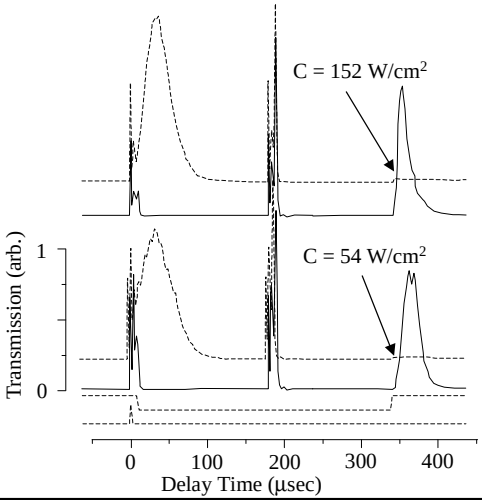
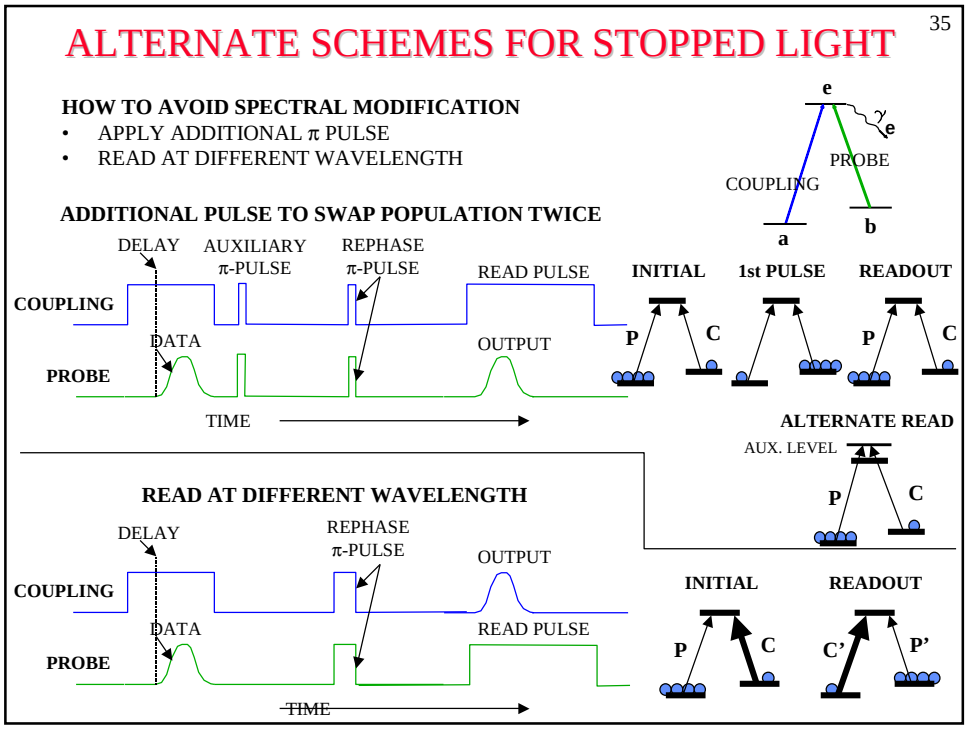
STOPPING DECELERATED LIGHT

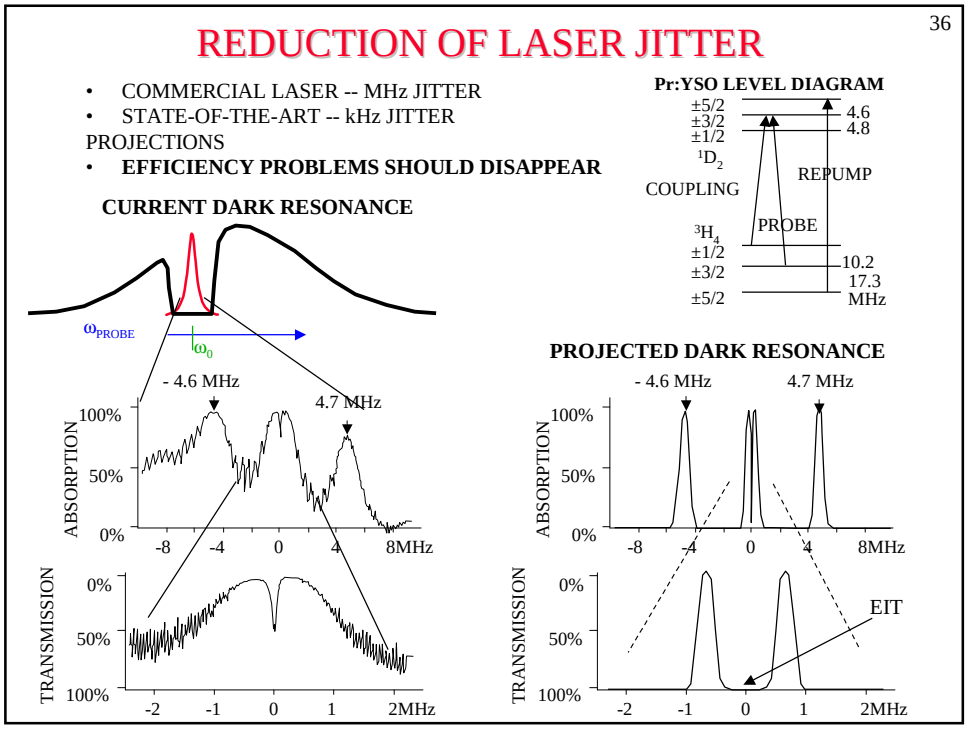
FIRST DECELERATE, THEN STOP THE LIGHT

- **EFFICIENCY MORE CONSISTENT WITH 0.5 msec SPIN LIFETIME**
- ECHO AMPLITUDE NOW INDEPENDENT OF COUPLING INTENSITY
- PROBE & COUPLING FIELDS BOTH STRONG -- POPULATIONS NEARLY EQUAL
- REPHASING PULSE HAS SMALLER EFFECT



Input probe width: 3 μsec. Rephasing: 8 μsec
Intensities: Strong C = 543 W/cm²,
P = 374 W/cm², R = 95
Rephasing intensities: C = 543 W/cm², P = 374


35
ALTERNATE SCHEMES FOR STOPPED LIGHT
HOW TO AVOID SPECTRAL MODIFICATION
• APPLY ADDITIONAL π PULSE
• READ AT DIFFERENT WAVELENGTH
ADDITIONAL PULSE TO SWAP POPULATION TWICE
e
γe
PROBE
COUPLING
a
b
DELAY
AUXILIARY π-PULSE
REPHASE π-PULSE
READ PULSE
INITIAL
1st PULSE
READOUT
COUPLING
DATA
OUTPUT
PROBE
P
C
TIME
ALTERNATE READ
AUX. LEVEL
READ AT DIFFERENT WAVELENGTH
DELAY
REPHASE π-PULSE
OUTPUT
COUPLING
DATA
READ PULSE
PROBE
INITIAL
READOUT
C'
P'
TIME


36
REDUCTION OF LASER JITTER
• COMMERCIAL LASER -- MHz JITTER
• STATE-OF-THE-ART -- kHz JITTER
PROJECTIONS
• EFFICIENCY PROBLEMS SHOULD DISAPPEAR
Pr:YSO LEVEL DIAGRAM
±5/2
±3/2
±1/2
4.6
4.8
1D2
REPUMP
COUPLING
PROBE
3H4
±1/2
±3/2
±5/2
10.2
17.3
MHz
CURRENT DARK RESONANCE
ωPROBE
ω0
- 4.6 MHz
4.7 MHz
ABSORPTION
100%
50%
0%
-8
-4
0
4
8MHz
TRANSMISSION
0%
50%
100%
-2
-1
0
1
2MHz
PROJECTED DARK RESONANCE
- 4.6 MHz
4.7 MHz
ABSORPTION
100%
50%
0%
-8
-4
0
4
8MHz
TRANSMISSION
0%
50%
100%
EIT
-2
-1
0
1
2MHz

37

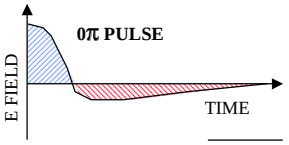
PRECISION ANTI-HOLE PREPARATION IN Pr:YSO

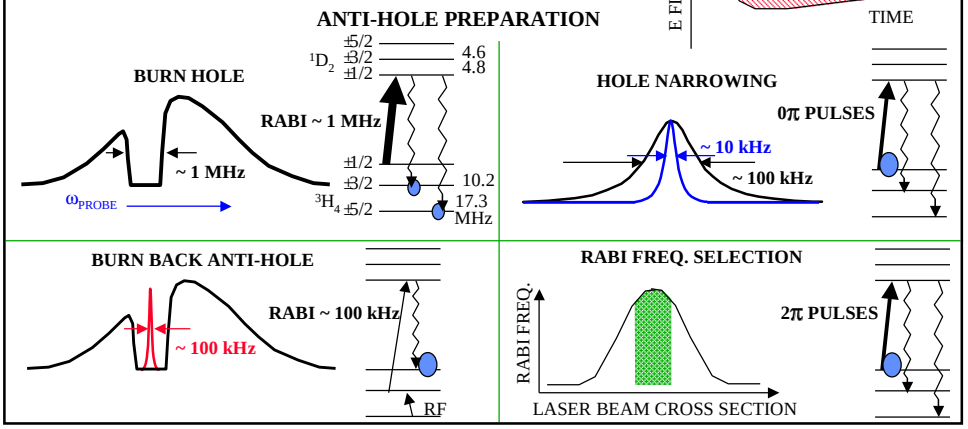
MAT SELLARS -- A.N.U.

- ~ 1 kHz LASER JITTER
- BURN HOLE WITH STRONG LASER ~ 1 MHz
- CREATE ANTI-HOLE WITH WEAKER LASER ~ 100 kHz
  - WIDTH LIMITED BY SPIN INHOMOGENEOUS

REFINE ANTI-HOLE

- 0- π PULSES TO NARROW FURTHER
- 2- π PULSES TO SELECT OPTICAL RABI FREQUENCY
  - LASER INTENSITY VARIATIONS





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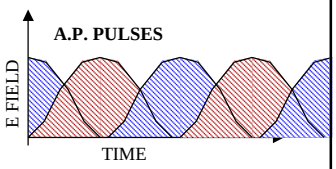
PRECISION ANTI-HOLE PREPARATION FOR STOPPED LIGHT STORAGE

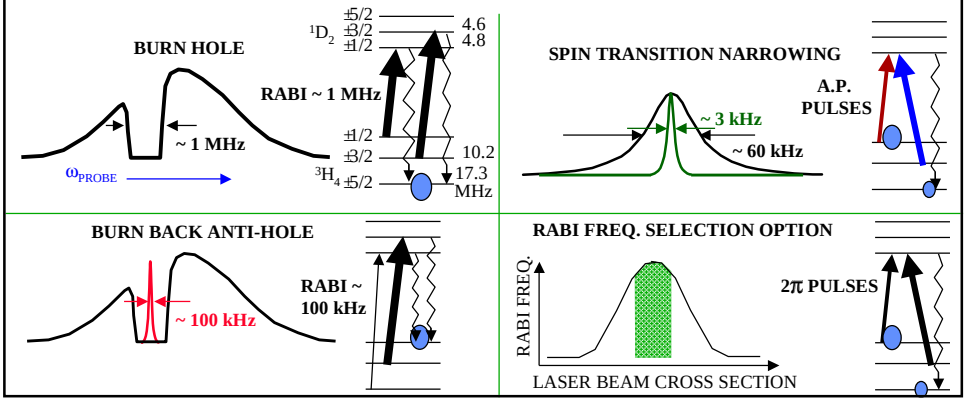
NEED TRANSPARENCY ON COUPLING TRANSITION

- KEEP ONE SUBLEVEL UNOCCUPIED

NARROW SPIN INHOMOGENEOUS LINE

- ADIABATIC PASSAGE PULSES
  - NON-RAMAN RESONANT ATOMS OPT. PUMPED
  - ADIABATIC CONDITION VIOLATED
- 2π PULSES TO SELECT OPTICAL RABI FREQUENCY





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PROSPECTS FOR SINGLE PHOTON STORAGE IN Pr:YSO

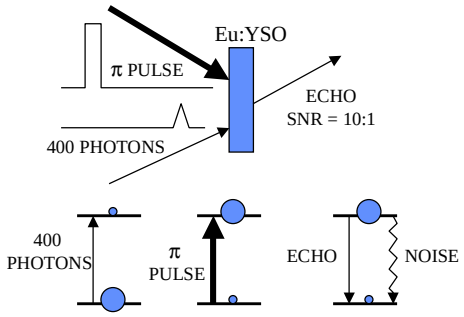
MAT SELLARS -- A.N.U.

- 400 PHOTONS STORED
- CONVENTIONAL ECHO
- SNR 10:1
  - SIGNAL COHERENT, NOISE INCOHERENT

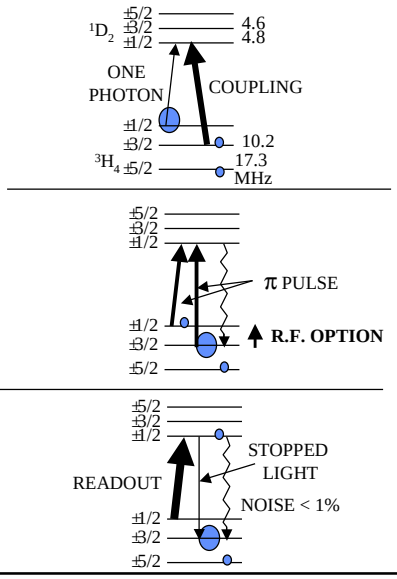
STOPPED LIGHT STORAGE

- NO SPONTANEOUS EMISSION NOISE
- IMPERFECTIONS IN REPHASING ?
  - ESTIMATED ~ 1%
  - RF REPHASING

FEW-PHOTON ECHO STORAGE DEMO



SINGLE-PHOTON STOPPED LIGHT



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EXTEND STORAGE TIME

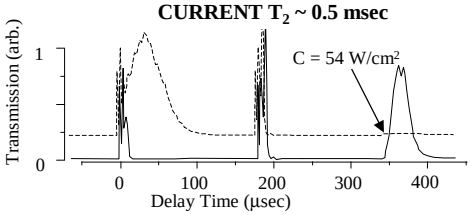
CURRENT STORAGE TIME

- LIMITED BY 0.5 msec T_2
- BUT T_1 ~ MINUTES
- THEORETICALLY CAN LENGTHEN T_2 TO BE NEAR T_1

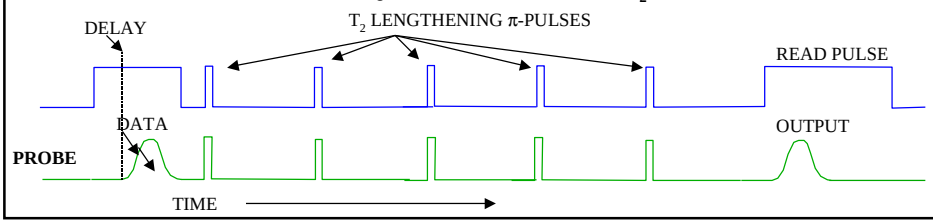
EXPERIMENTALLY DEMONSTRATED IN LIQUID NMR (CORY)

- T_2 LENGHTENED FROM msec TO ~ min

CURRENT T_2 ~ 0.5 msec



SAMPLE PULSE SEQUENCE TO LENGTHEN T_2



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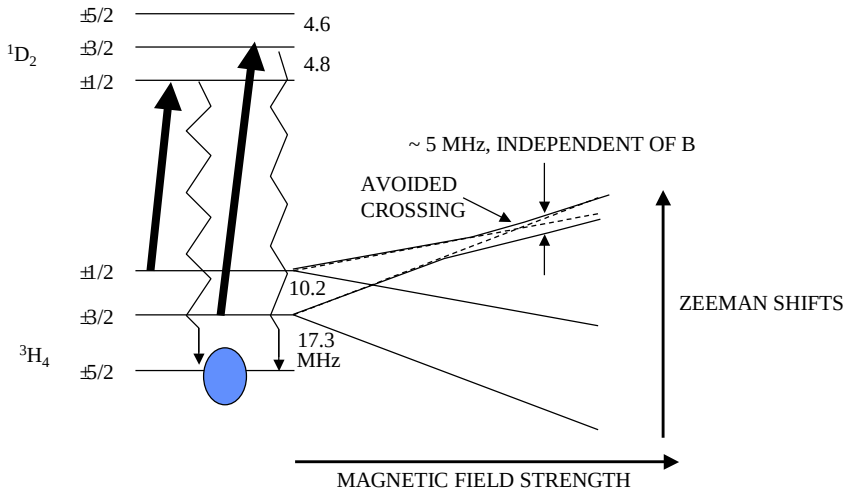
DEMONSTRATED LONG STORAGE TIME IN Pr:YSO

MAT SELLARS - A.N.U.

- TUNE MAGNETIC FIELD TO MINIMUM ZEEMAN EFFECT
  - AVOIDED CROSSING
- REPHASING TIME ~ 20 msec



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SUMMARY

OBSERVED ULTRA-SLOW AND STOPPED LIGHT IN A SOLID

- ROLE OF EIT VERIFIED
- ACCELETATION AND DECELERATION ALSO OBSERVED

SOLID PREDICTED TO ACT LIKE WARM VAPOR

- EXPERIMENTALLY ACTED MORE LIKE ULTRA-COLD VAPOR
- REPUMP CREATES ANTI-HOLE -- NARROW LINEWIDTH

ANAMOLOUSLY SLOW LIGHT SPEED

- ANTI-HOLE BURNING ALSO TAKES PLACE IN PRESENCE OF EIT
- CAN USE TO GET HIGH EFFICIENCY