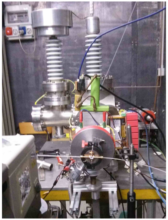
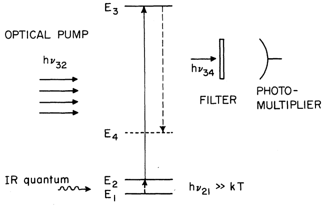
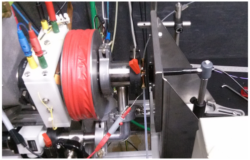




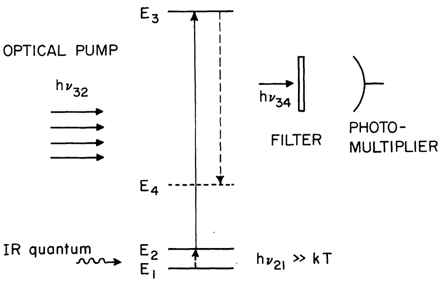


Particle detection through the quantum counter concept in YAG:Er^{3+}

C. Braggio, F.A. Borghesani, G. Carugno, F. Chiossi, M. Guarise
University of Padova and INFN
M. Tonelli, A Di Lieto
University of Pisa and INFN

THE INFRARED QUANTUM COUNTER CONCEPT

N. Bloembergen, *Phys. Rev. Lett.* **2**, 84 (1959)



- pump laser resonant with transition $2 \rightarrow 3$
- material transparent to the pump until an IR photon is absorbed ($1 \rightarrow 2$)
- level 3 is fluorescent $\Longrightarrow$ detection can be accomplished via conventional detectors (PMT or PD)
- such energy level scheme can be realized in wide bandgap materials doped with trivalent rare-earth ions

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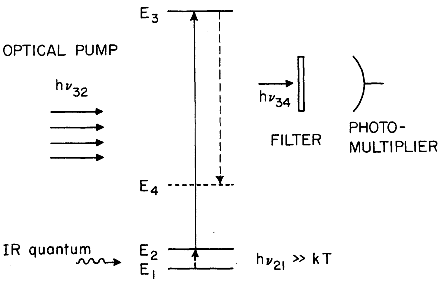

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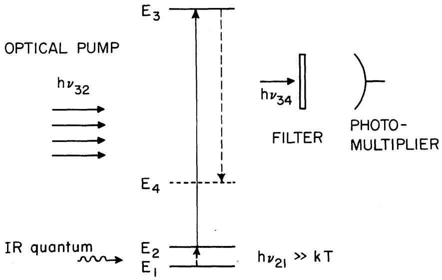

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the whole field of **upconversion** can be traced back to this idea

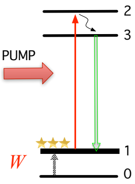
1. IR detection demonstrated up to $\lambda \sim 20\,\mu$m in ruby (APL **29**, 566 (1976))
2. $\lambda \sim 2\,\mu$m photons detected with unitary efficiency in $LaCl_3$:Pr^{3+} and LaF_3:Pr^{3+} (JAP **44**, 781 (1973))

MOTIVATION

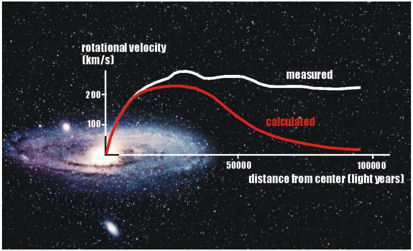
Development of a *low threshold*, *large volume* particle detector for fundamental physics searches

$W \Longleftrightarrow$ threshold, sensitivity and resolution

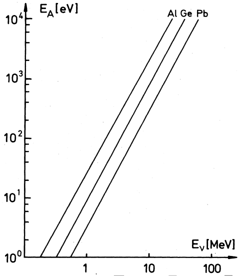
analogous to the mean energy required to produce an *e-h* pair in semiconductors (~ 3.6 in Si) or per ion pair, say, in liquid Ar (26.4 eV)



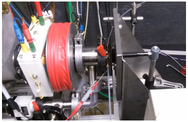
axionic dark matter:"invisible axion" mass constrained in the range $1\,\mu$eV–10 meV

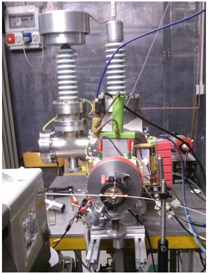


coherent neutrino-nucleon scattering

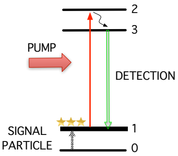


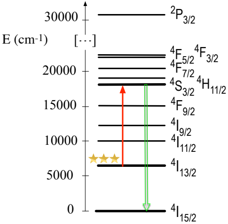
THE IRQC IDEA APPLIED TO PARTICLE DETECTION: A DEMONSTRATION

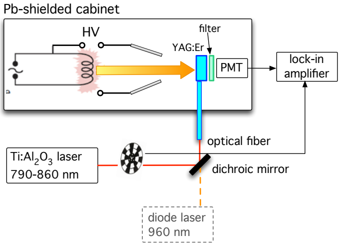




YAG:Er^{3+}







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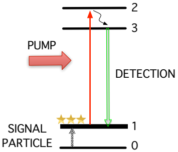

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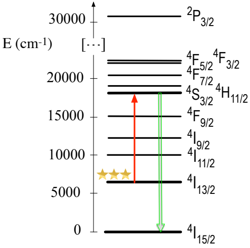
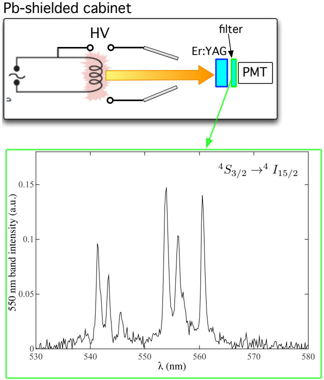
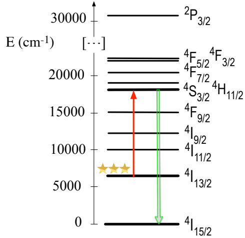
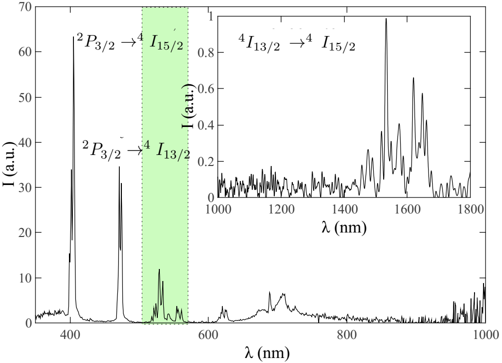




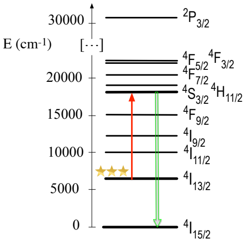
IR (NARROWBAND) VS PARTICLE (WIDEBAND) EXCITATION

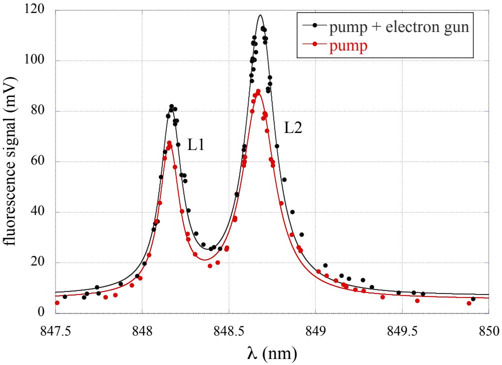
the cathodoluminescence spectrum





L1, L2 transitions between sublevels in the $^4I_{13/2}$ and $^4S_{3/2}$





- the fluorescence signal is greater when the electron gun excites the crystal

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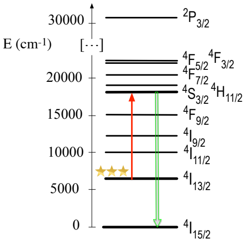

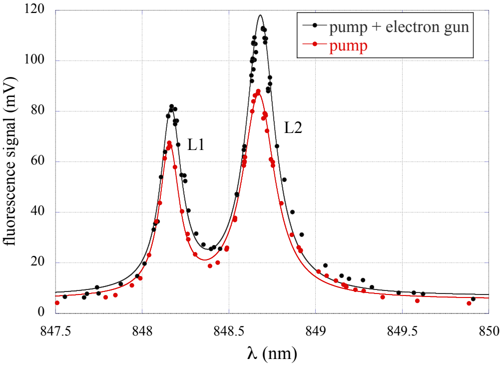

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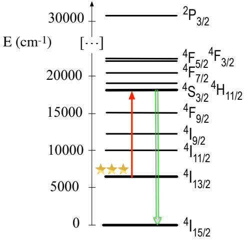

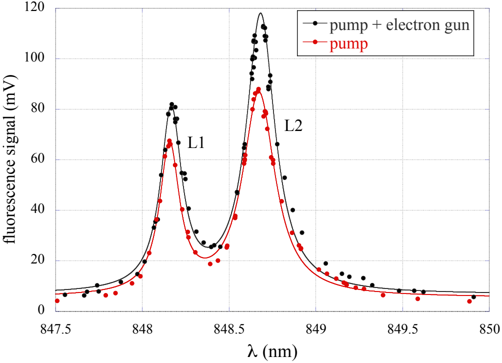

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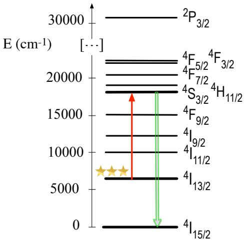
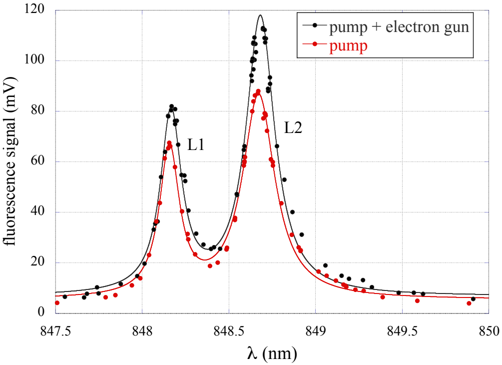


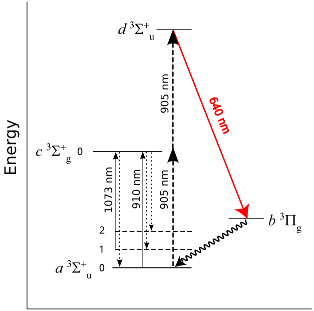


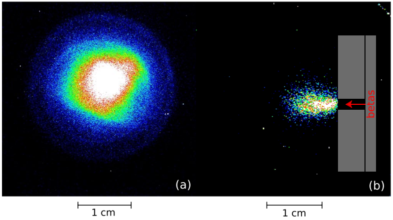
- the fluorescence signal is greater when the electron gun excites the crystal
- a significant fraction of the fluorescence is determined by the pump laser double resonance
- e^- excitation geometrically unfavorite as compared to pump laser double resonance
- host crystal (YAG) has a weak IRQC output

FINDING THE RIGHT MEDIA

MATERIAL IN WHICH A *re-cycle* PROCESS CAN BE INITIATED

Example: triplet state molecules in superfluid He





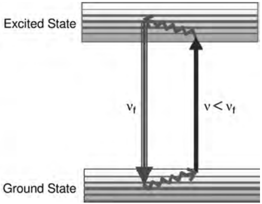
ionizing radiation events imaging
PRL 100, 025301 (2008)

FINDING THE RIGHT MEDIA

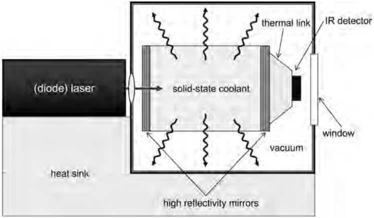
EXPLOIT THE PHONON CHANNEL FOR DETECTION

a dominant process is the thermalization of the secondary electrons produced in the particle interaction that takes place through optical *phonon scattering*

Example: optical refrigeration/laser cooling of solids



anti-Stokes fluorescence/
luminescence upconversion cooling



phonon absorption followed by blueshifted fluorescence that carries away heat