

UV Generation from Solid State Lasers

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OUTLINE

Background

Direct laser sources

Nonlinear generation schemes



Direct electronic transitions in gases, liquids and solids can be accessed with UV light

- **Useful in basic scientific studies**
- **Application to cutting of "difficult" materials**
Plastics, ceramics, corneal tissue
- **Strong absorption leads to sensitive detection of atmospheric components by differential absorption and/or fluorescence lidar**

Short- wavelength sources lead to higher resolutions in lithography - coherent sources have both required power and spectral narrowness



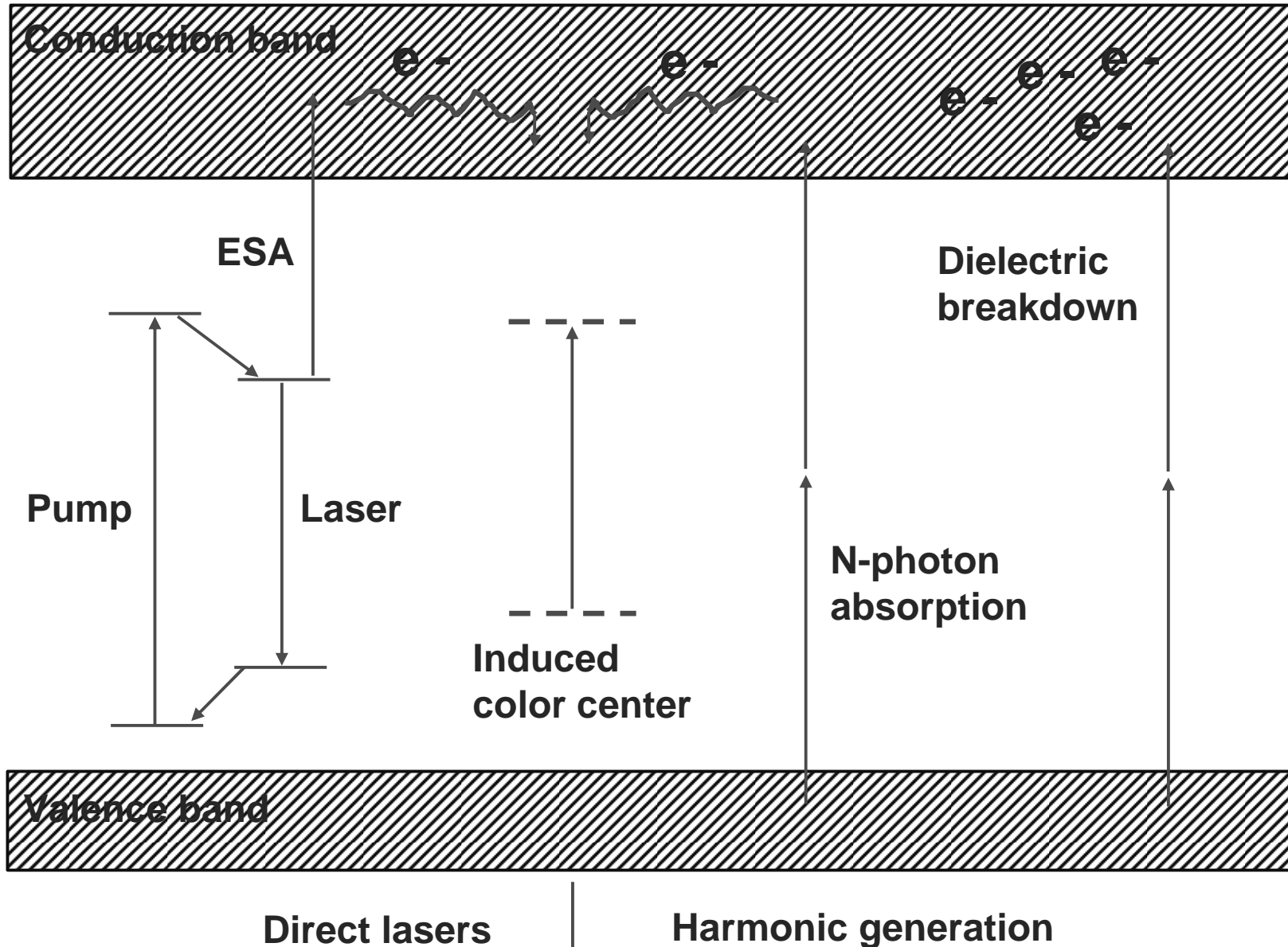
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WHY SOLID STATE vs. EXCIMER?

- n **No gases, high-voltage discharges**
 - **Safety**
 - **Reduced size, operating expense**
 - **Reliability?**
- n **Tunability**
 - **Critical for atomic, molecular spectroscopy, sensing**
- n **More versatility in operating modes**
 - **CW**
 - **High pulse rate**
 - **Femtosecond**



COMMON PROBLEMS IN UV GENERATION





Paramagnetic ion lasers based on 4f-4f transitions (rare earths) or 3d-3d transitions (transition metals) generally have small splittings between levels, leading to laser operation in the visible-near-IR

In rare earths, transitions between 5d-4f levels are in the UV-visible wavelength range, leading to the possibility of direct laser operation in the UV

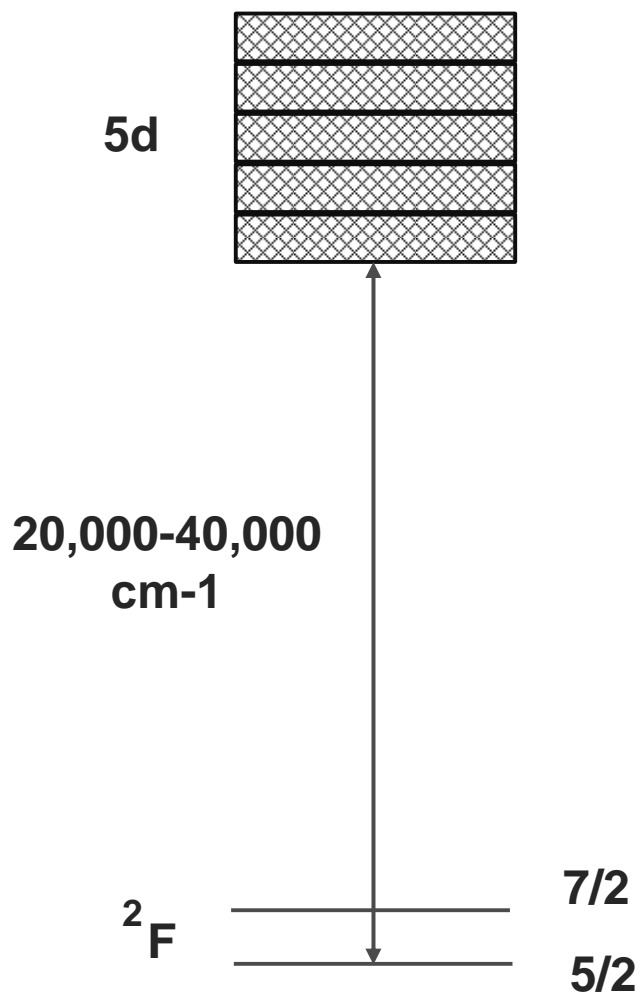
5d-4f transitions are

- Parity allowed, and thus have ns lifetimes**
- Spectrally broad, due to a large lattice shift between 5d and 4f configurations**
- 4-level in nature due to lattice shift**



TRIVALENT CERIUM ENERGY LEVELS

- n Trivalent cerium (Ce) has one electron in outer shell
- n Ground state of electron is 4f, with two levels split 2300 cm⁻¹ by spin-orbit coupling
- n Next state is 5d, with energy and state splitting strongly influenced by host crystal
- n Large difference between 5d and 4f states leads to a large lattice shift and resultant broad, Stokes-shifted absorption and emission





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5d-4f LASERS: SUMMARY

Material	Pump	Output Wavelength (nm)
Ce:LaF ₃	248 nm	286
Ce:LiCAF	266 nm	281-315
Ce:LiSAF	266 nm	283-313
Ce:YLF	248 nm	306-315 323-328
Ce:LLF	248 nm	325



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UV GENERATION VIA NONLINEAR OPTICS

ⁿ Recent technology advances of note:

- **High-damage threshold nonlinear materials with excellent UV transparency: BBO, LBO, CLBO**
- **High-power, tunable IR sources for drivers: Ti:sapphire, Cr:LiSAF**
- **Diode-pumped Nd-doped lasers**
High-power, single-frequency CW sources
High-beam-quality pulsed sources



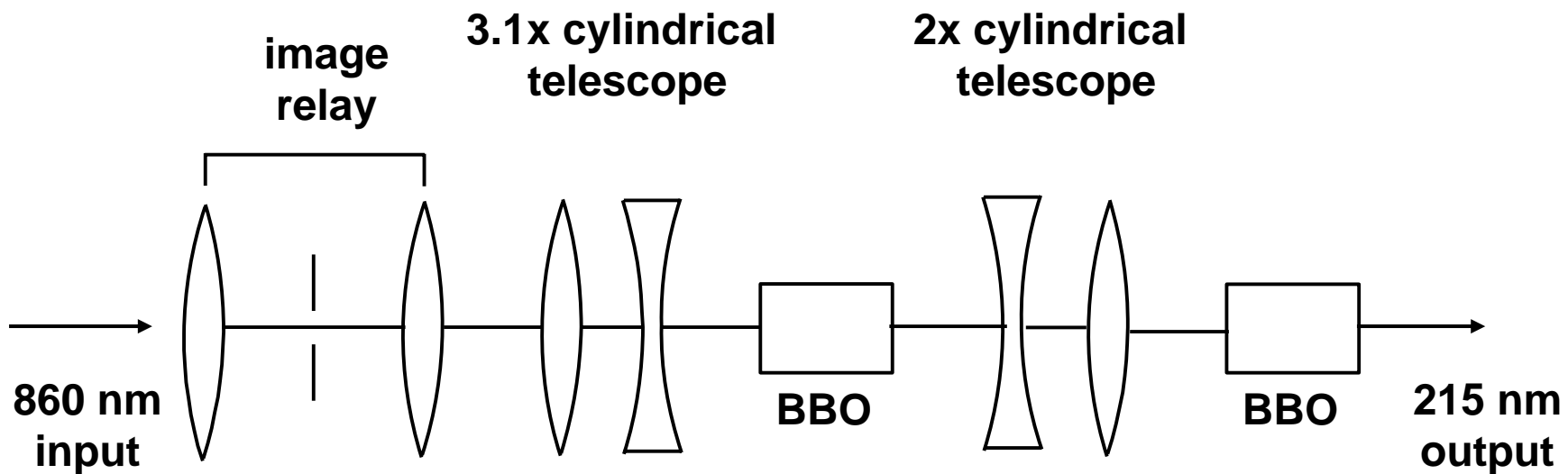
PROPERTIES OF NONLINEAR MATERIALS

Crystal	d (pm/V)	Refractive e	d ² /n ³	Transparen cy (nm)
KTP	d ₂₄ =3.9 d ₁₅ =2.04	n _x =1.74 n _y =1.75 n _z =1.83	2.7	350-3500
BBO	d ₂₁ =-2.3	n _o =1.66 n _e =1.54	1.3	189-3500
LBO	d ₃₁ =0.85 d ₃₂ =-.67	n _x =1.57 n _y =1.59 n _z =1.61	0.18	160-2600
CLBO	d ₃₆ =0.8?	n _o =1.50 n _e =1.45	0.19?	180-2750



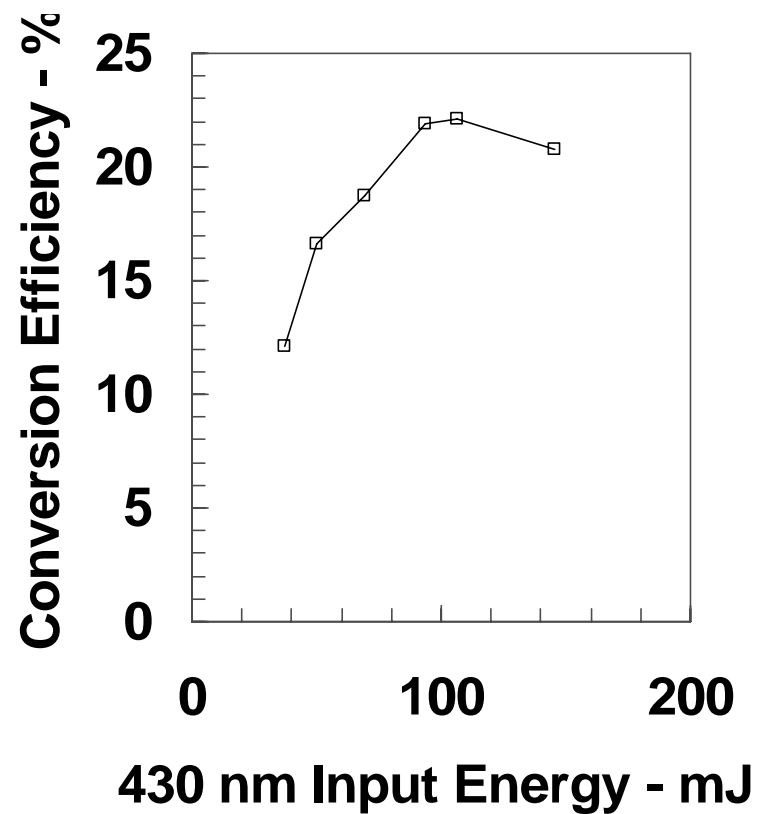
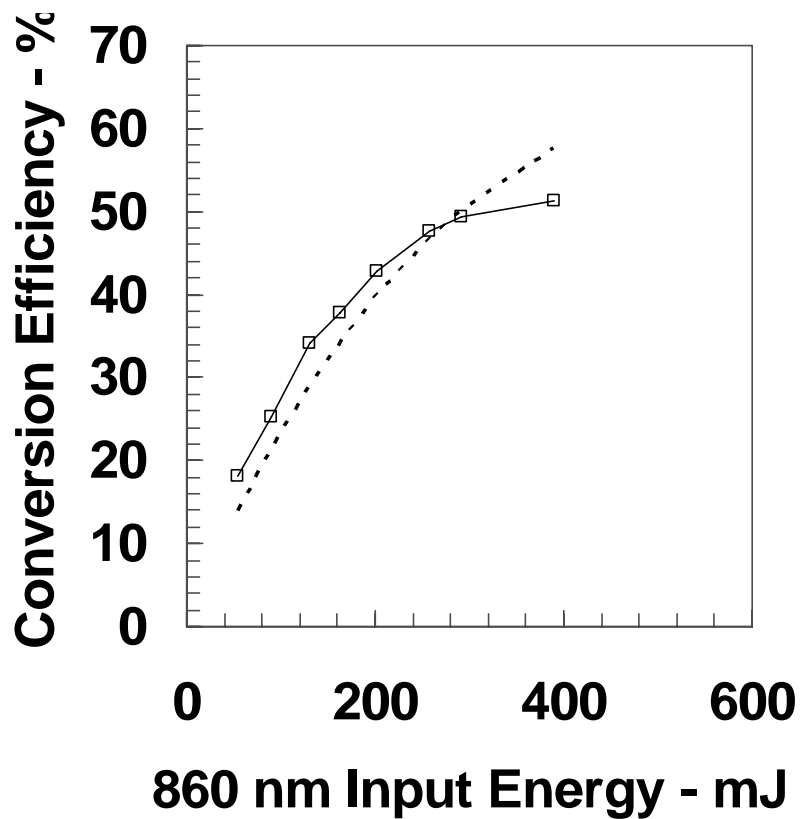
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Cr:LiSAF FOURTH-HARMONIC GENERATOR





I/O DATA ON Cr:LiSAF GENERATION





Direct generation of UV from solid state sources is possible in the region around 300 nm, at energy levels on the order of 10 mJ. Shorter wavelengths (172 nm) have been observed with much lower energies.

Harmonic processes, coupled with tunable solid state drive lasers, can cover the entire UV region and into the VUV. They also permit cw generation with resonant enhancement.

Harmonic generation will be more energetic than direct generation as long as solid state pump sources are employed. Excimer or incoherent pump sources for 5d-4f lasers would change this.