Spin & Symmetry

Fermions (spin 1/2, 3/2, 5/2 etc) must have antisymmetric wave functions with respect to interchange of 2 identical particles.

Bosons (spin 0, 1, 2, etc) must have symmetric wave functions with respect to interchange of 2 identical particles.

Two electrons in infinite square well: lowest energy state?

Both electrons in n = 1, one with m_s = ½ the other with -1/2

$\psi = \psi_1(x_1)\,\psi_1(x_2)\,(|s_1,1/2\rangle|s_2,-1/2\rangle - |s_1,-1/2\rangle|s_2,1/2\rangle)/2^{1/2}$

Without symmetry requirement there are 4 lowest states.

Spin & Symmetry

Two electrons in infinite square well: first excited state?

One electron in n = 1, the other in n = 2. There are 4 independent states with the same energy:

$$\psi = [\psi_1(x_1)\,\psi_2(x_2)+\psi_2(x_1)\,\psi_1(x_2)]\,(|1/2>|-1/2> - |-1/2>|1/2>)/2$$

$$\psi = [\psi_1(x_1)\,\psi_2(x_2)-\psi_2(x_1)\,\psi_1(x_2)]\,(|1/2>|-1/2> + |-1/2>|1/2>)/2$$

$$\psi= [\psi_1(x_1)\,\psi_2(x_2)-\psi_2(x_1)\,\psi_1(x_2)]\,|1/2>|1/2>/2^{1/2}$$

$$\psi= [\psi_1(x_1)\,\psi_2(x_2)-\psi_2(x_1)\,\psi_1(x_2)]\,|-1/2>|-1/2>/2^{1/2}$$

Order for adding electrons

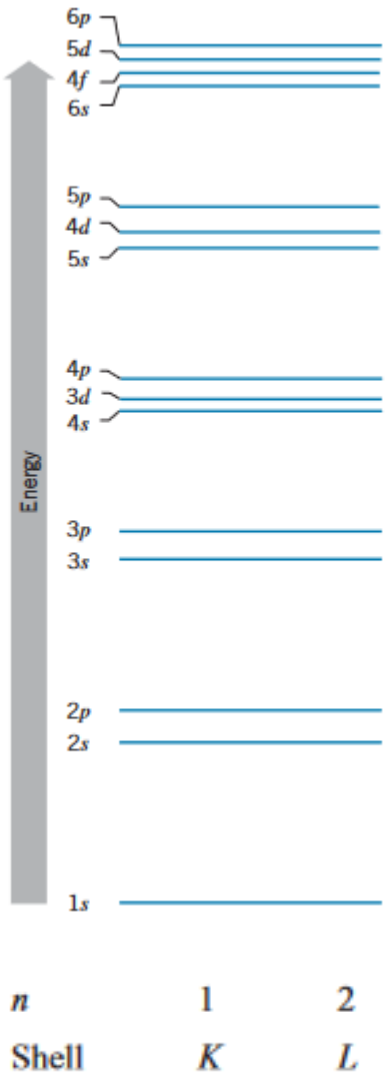


TABLE 8.1 Filling of Atomic Subshells

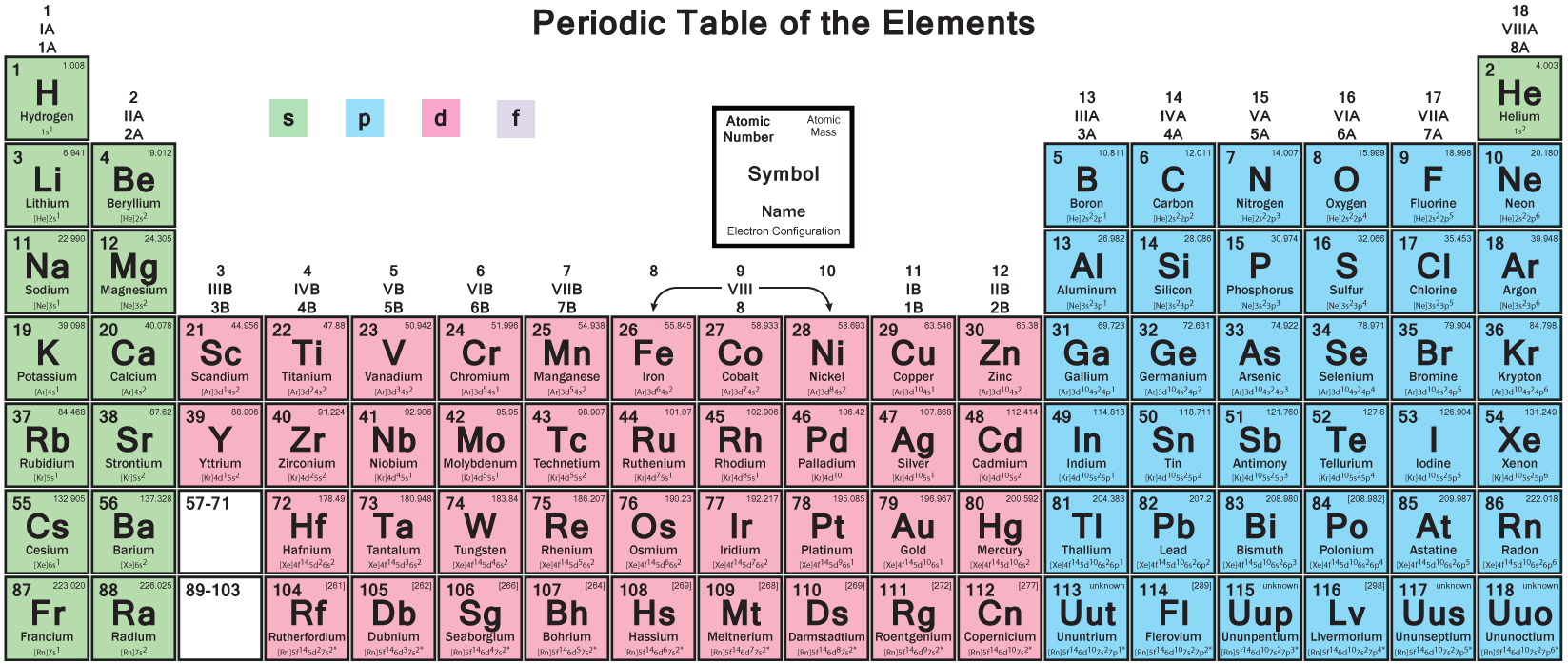
n	l	Subshell	Capacity $2(2l+1)$
1	0	1*s*	2
2	0	2*s*	2
2	1	2*p*	6
3	0	3*s*	2
3	1	3*p*	6
4	0	4*s*	2
3	2	3*d*	10
4	1	4*p*	6
5	0	5*s*	2
4	2	4*d*	10
5	1	5*p*	6
6	0	6*s*	2
4	3	4*f*	14
5	2	5*d*	10
6	1	6*p*	6
7	0	7*s*	2
5	3	5*f*	14
6	2	6*d*	10

The order of energies for electrons in atoms determines the periodic table.

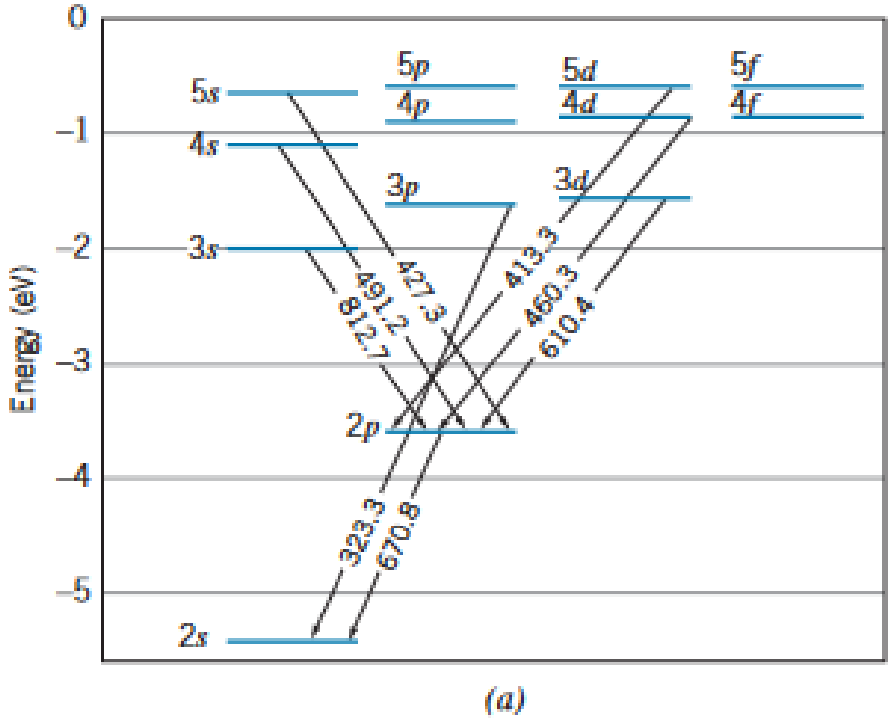
The potential energy vs. r goes strongly negative as r goes to 0.

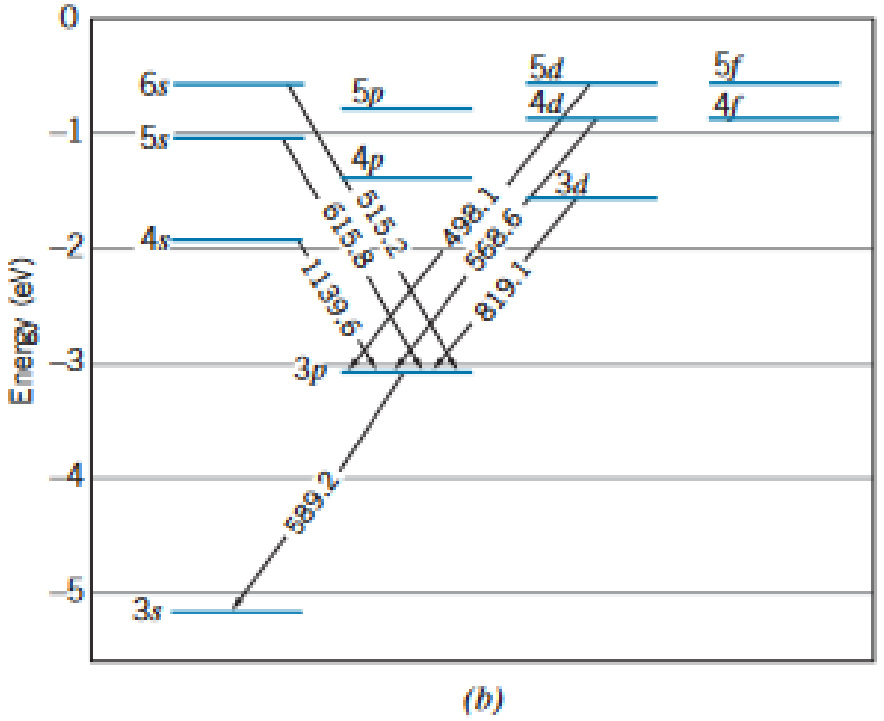
Angular momenta that can get to small r are more strongly shifted to more deeply bound.

Periodic Table of the Elements



Dipole allowed, alkali





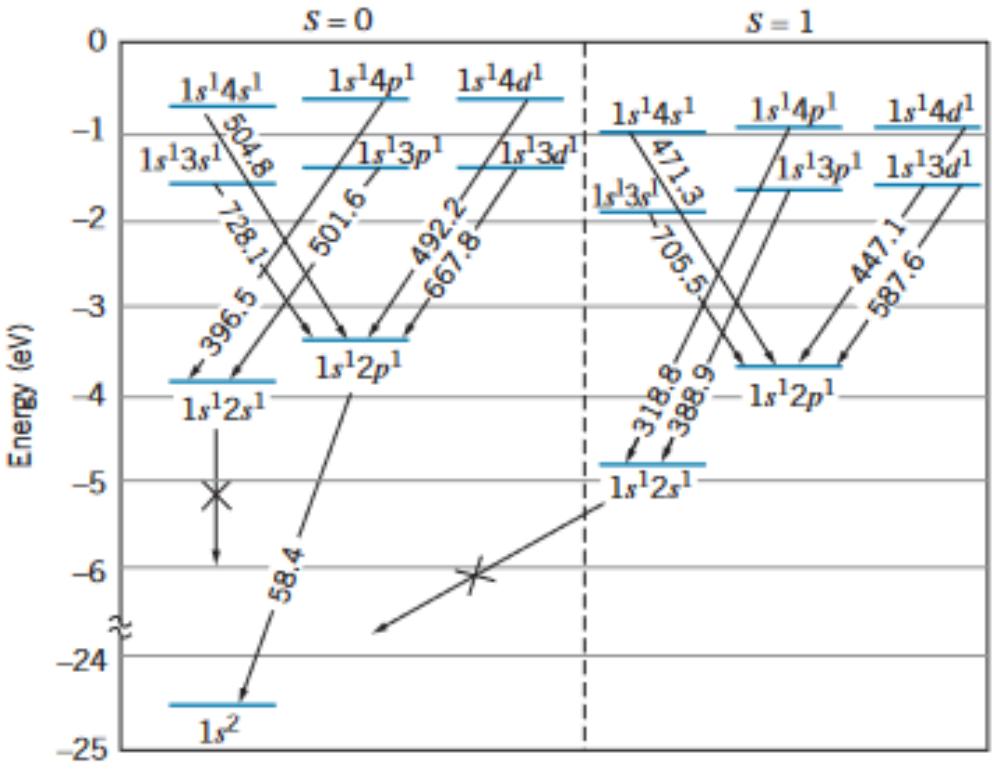
Li

Na

Quadrupole transitions allowed (but slower)

Li: 3d can go directly to 2s with 1 photon

Dipole allowed, He

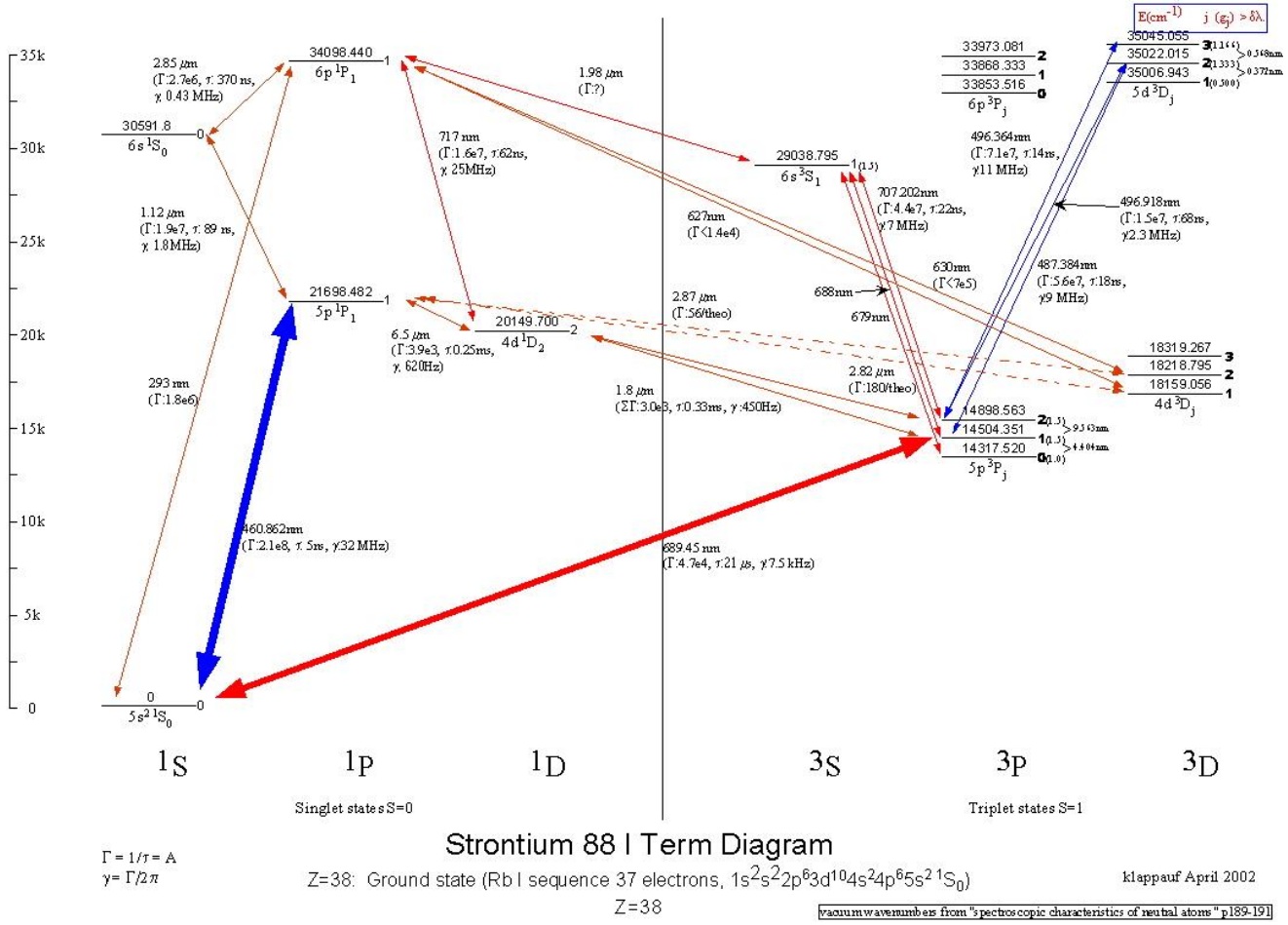


The 1s2s states are “metastable”. They go to the ground state by emitting 2 photons. The S=1 1s2s state has a much longer lifetime because the ground state has S=0

1s3d -> ground state is allowed but slow

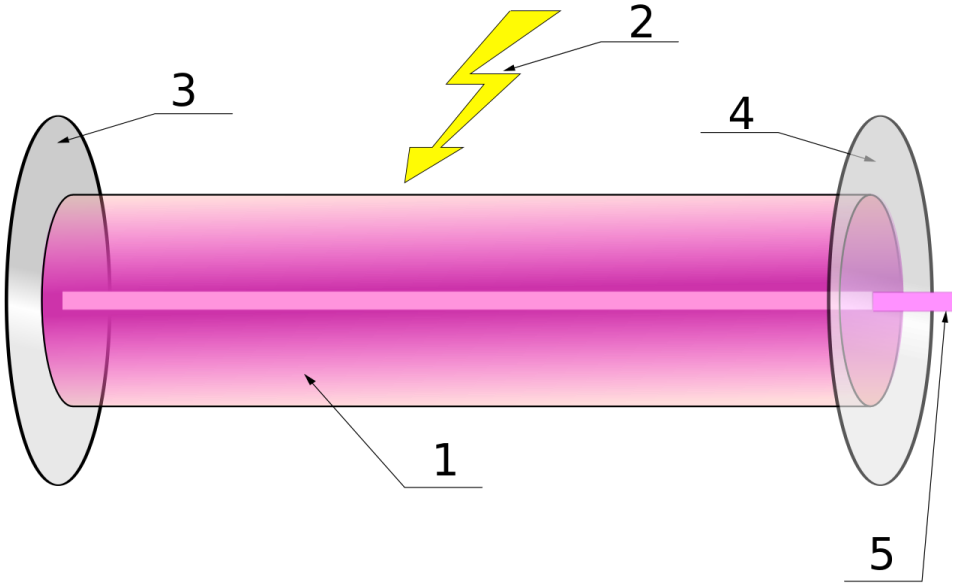
In plasma, a lot of population can get trapped in the 1s2s states.

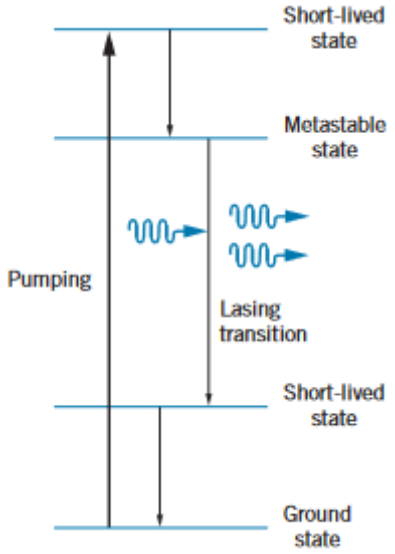
Dipole allowed, Sr



Sr is used in some of the most accurate atomic clocks. The 5s5p S=1 state with J=0 **cannot** emit a photon unless the Sr isotope has nuclear spin (lifetime 1000's of seconds).

Laser Basic





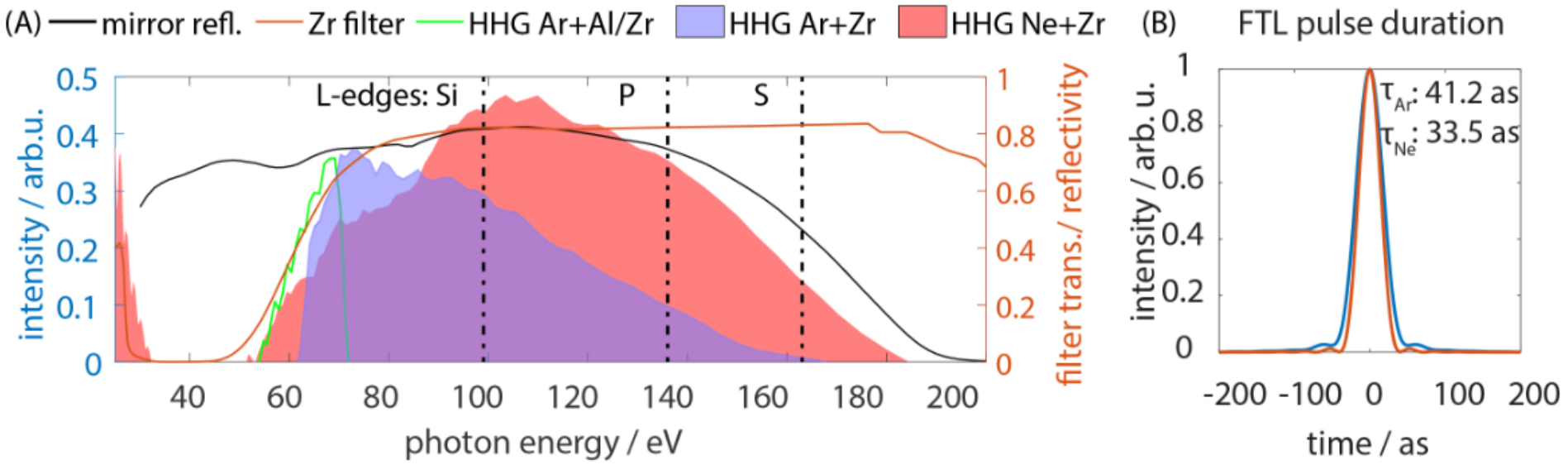
https://en.wikipedia.org/wiki/Laser

1=Gain medium
2=Pump energy in
3=Reflector
4=Reflector/output coupler
5=Laser beam

Light builds up between the mirrors leading to more stimulated light.

Coherent light with small frequency uncertainty

Shortest Laser Pulse



https://ethz.ch/en/news-and-events/eth-news/news/2017/10/worlds-shortest-laser-pulse.html

https://opg.optica.org/oe/fulltext.cfm?uri=oe-25-22-27506&id=375881

Streaking of 43-attosecond soft-X-ray pulses generated by a passively CEP-stable mid-infrared driver

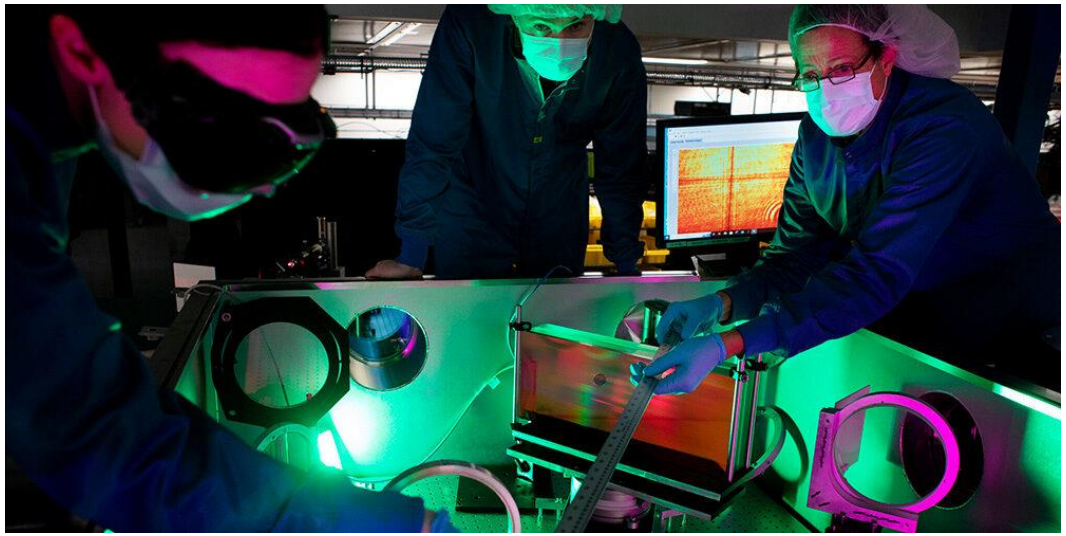
Thomas Gaumnitz, Arohi Jain, Yoann Pertot, Martin Huppert, Inga Jordan, Fernando Ardana-Lamas, and Hans Jakob Wörner

Many claims of shortest laser pulse (faster & faster)

Example of 43 attosec pulse

Why big photon energy range???

Strongest Laser Pulse



https://michigantoday.umich.edu/2022/09/23/first-light-at-the-most-powerful-laser-in-the-u-s-2/

https://www.sciencealert.com/scientists-are-about-to-fire-up-the-most-powerful-laser-in-the-us

https://www.nobelprize.org/prizes/physics/2018/summary/

Many claims of strongest laser pulse (stronger & stronger)

Example of 500 Terrawatts w/ max power 3 PetaW

Many different metrics for strongest

Highest intensity 10^{23} W/cm^2

https://www.sciencedaily.com/releases/2021/05/210506105445.htm