Sequential Double Ionization of Ar to Ar2+ Over Intense Laser Field Pulses

Kansas State REU 2023; Professor C.D. Lin and Dr. Isaac Yuen
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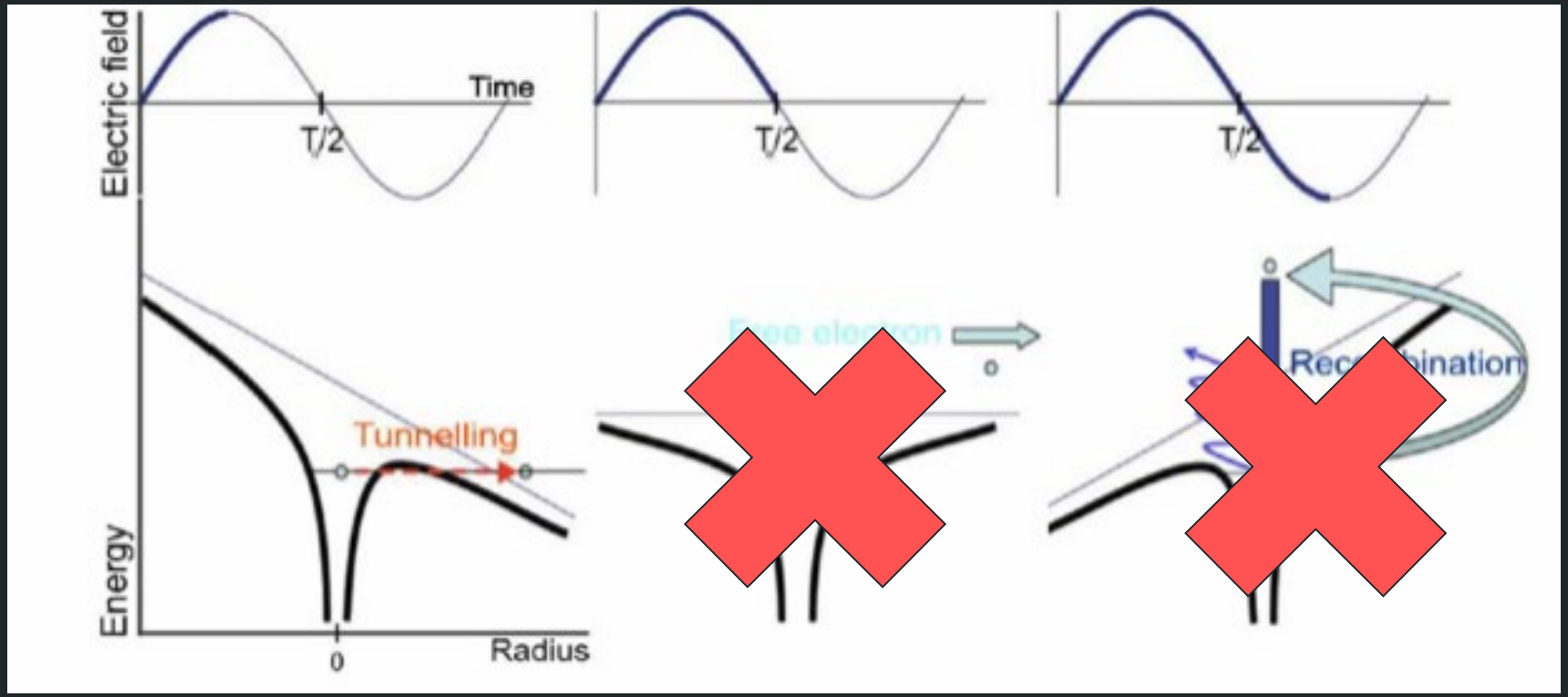
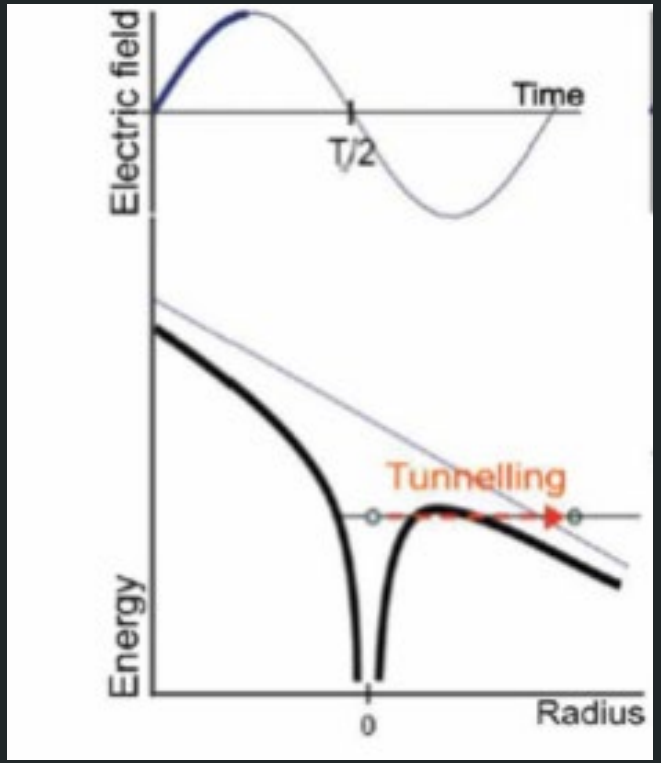
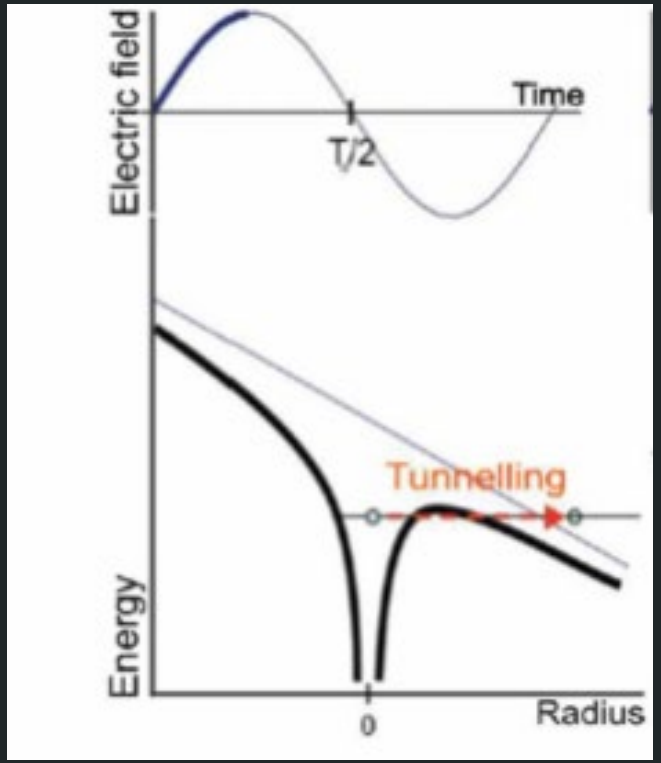
Three Step Model



Sequential Double Ionization

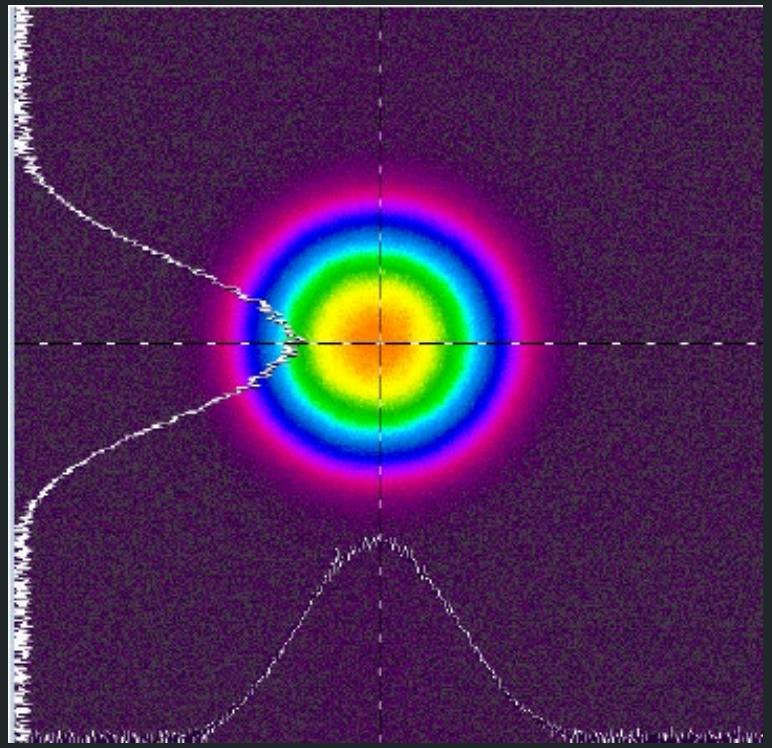




Laser Profiles

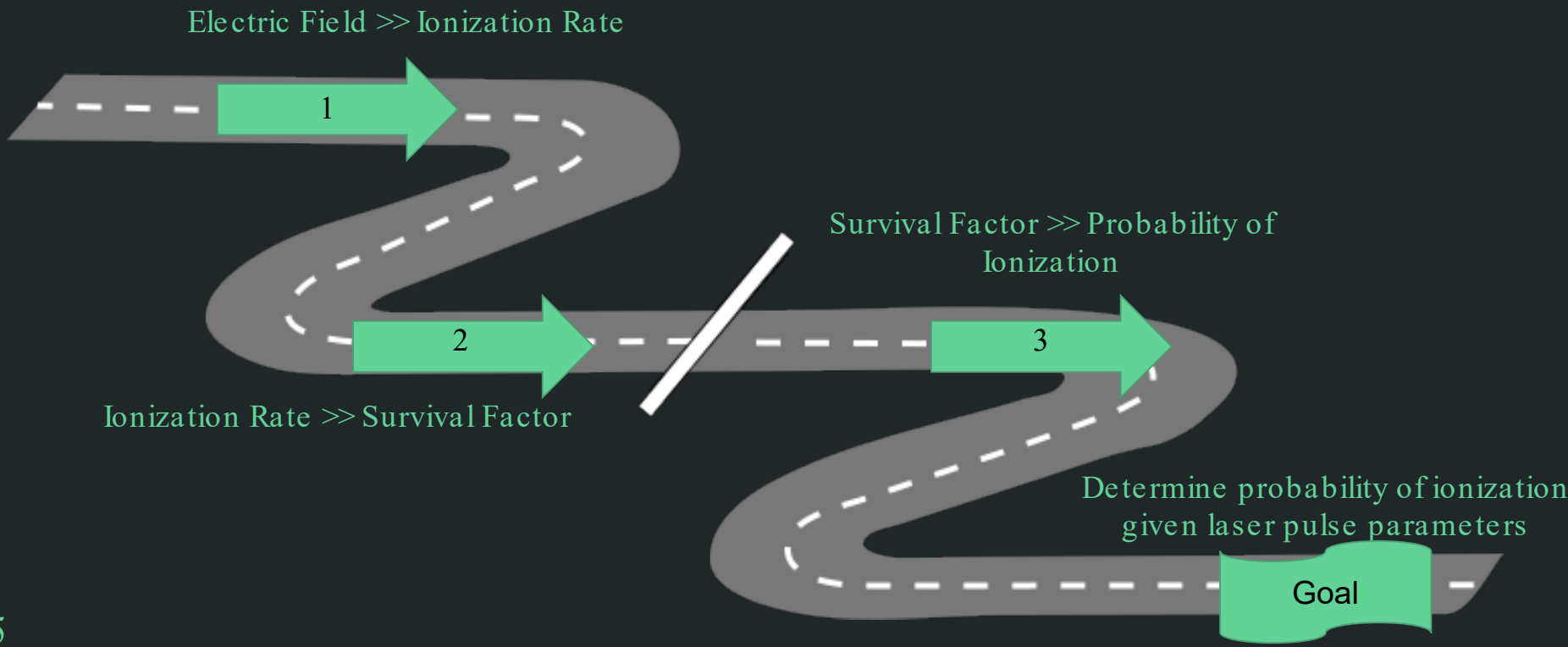
Intensities above $1x10^{15}$ W/cm^2 are too difficult to distinguish

We need a program to calibrate these profiles



Kim, Kyungbum, Peng, Xiang & Lee, **Proceedings of SPIE - The International Society for Optical Engineering** , (2014)

Pathway from Ar to Ar2+



Step 1

Ammosov-Delone-Krainov
theory plus modification:

$$W_{TI}(F) = \frac{C_l^2}{2^{|m|}|m|!} \frac{(2l+1)(l+|m|)!}{2(l-|m|)!} \frac{1}{\kappa^{2Z_c/\kappa-1}} \left(\frac{2\kappa^3}{F}\right)^{\frac{2Z_c}{\kappa}-|m|-1} e^{-2\kappa^3/3F}$$

$$W_{TBI}(F) = W_{TI}\, e^{-\alpha(Z_c^2/I_p)(F/\kappa^3)}$$

Tong, X.M., Lin, C.D., **Journal of Physics B: Atomic, Molecular, and Optical Physics.** 2595 (2005)

Step 2

Method 1

$$\frac{dP_0}{dt} = -P_0(t)\,W_0(t)$$

$$\int \frac{dP_0}{P_0(t)} = -\int W_0(t)\,dt$$

$$P_0(t) = e^{-\int W_0(t)\,dt}$$

$$\frac{P_1 \times P_2}{P_1}$$

Method 2

$$\text{Ar}: \quad \frac{dP_0}{dt} = -P_0(t)\,W_0(t)$$

$$\text{Ar}t: \quad \frac{dP_1}{dt} = -P_1(t)\,W_1(t) + P_0(t)\,W_0(t)$$

$$\text{Ar}2t: \quad \frac{dP_2}{dt} = P_1(t)\,W_1(t)$$

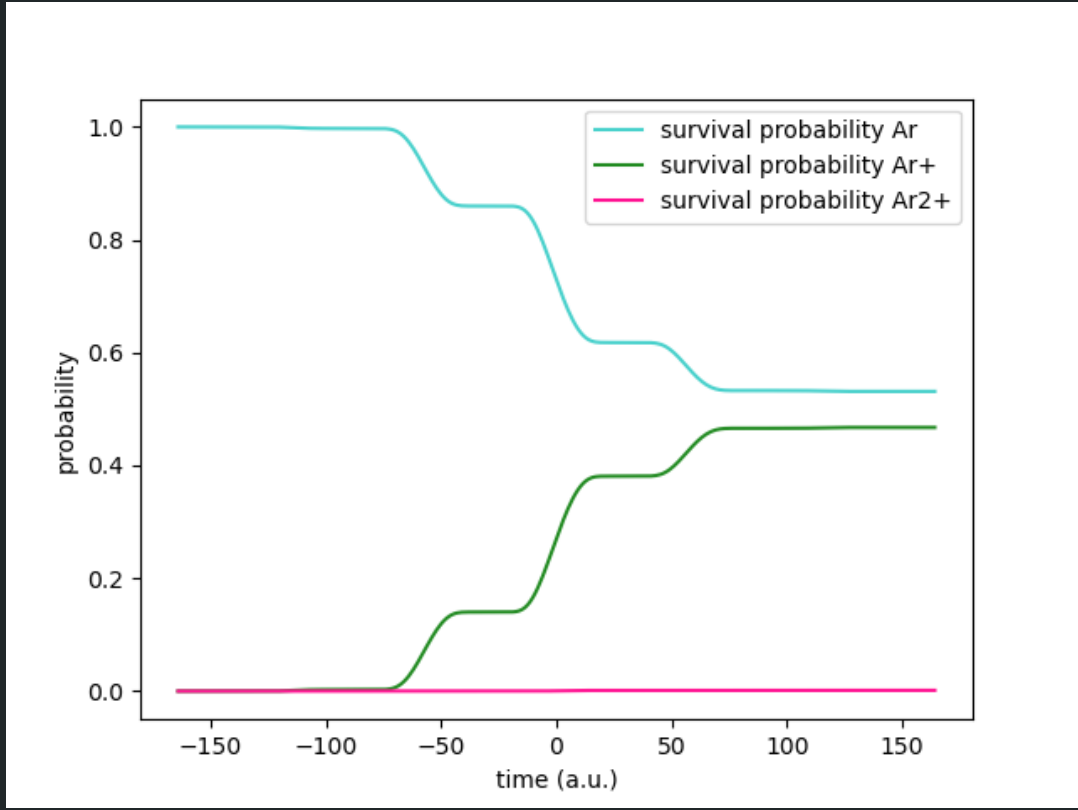
$$P_0(0) = 1$$

$$P_1(0) = 0$$

Lin, C.D., Yuen, I., **Physical Review** 023120 (2022)

Step 2

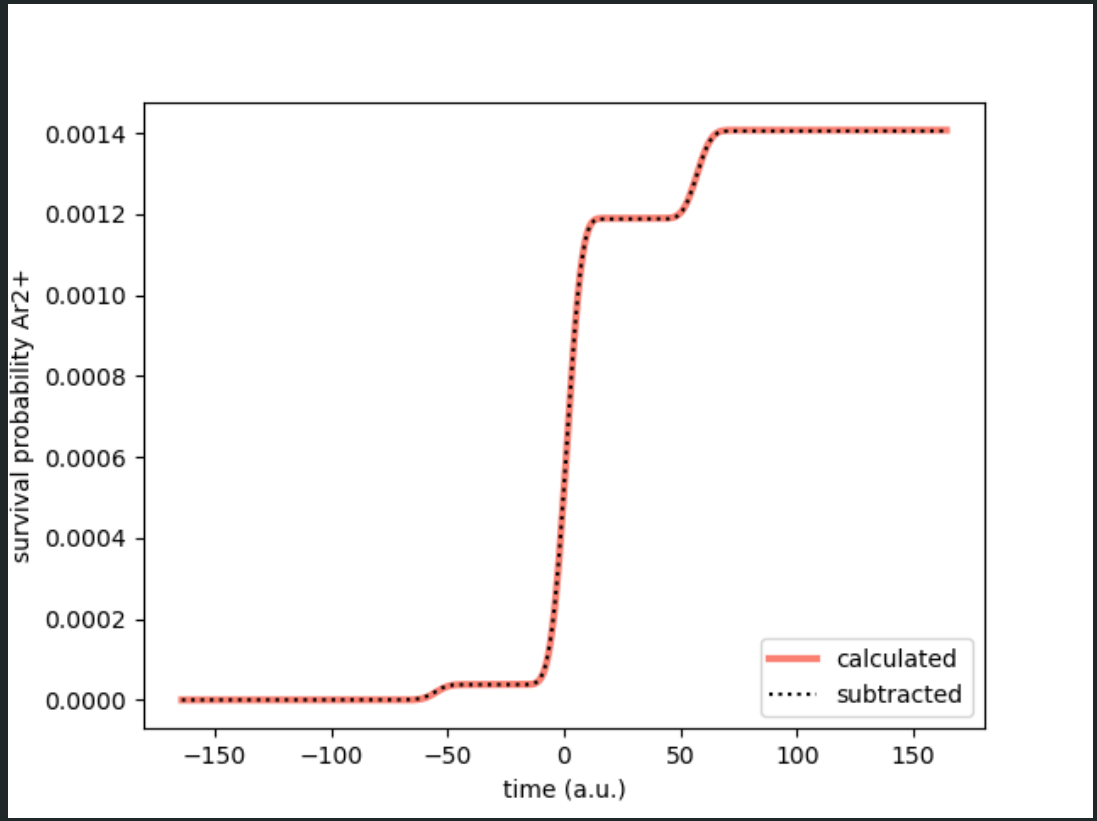
$$P_0 + P_1 + P_2 = 1$$



Lin, C.D., Yuen, I., "Density-matrix approach for sequential dissociative double ionization of molecules" **Physical Review** 023120 (2022)

Step 2

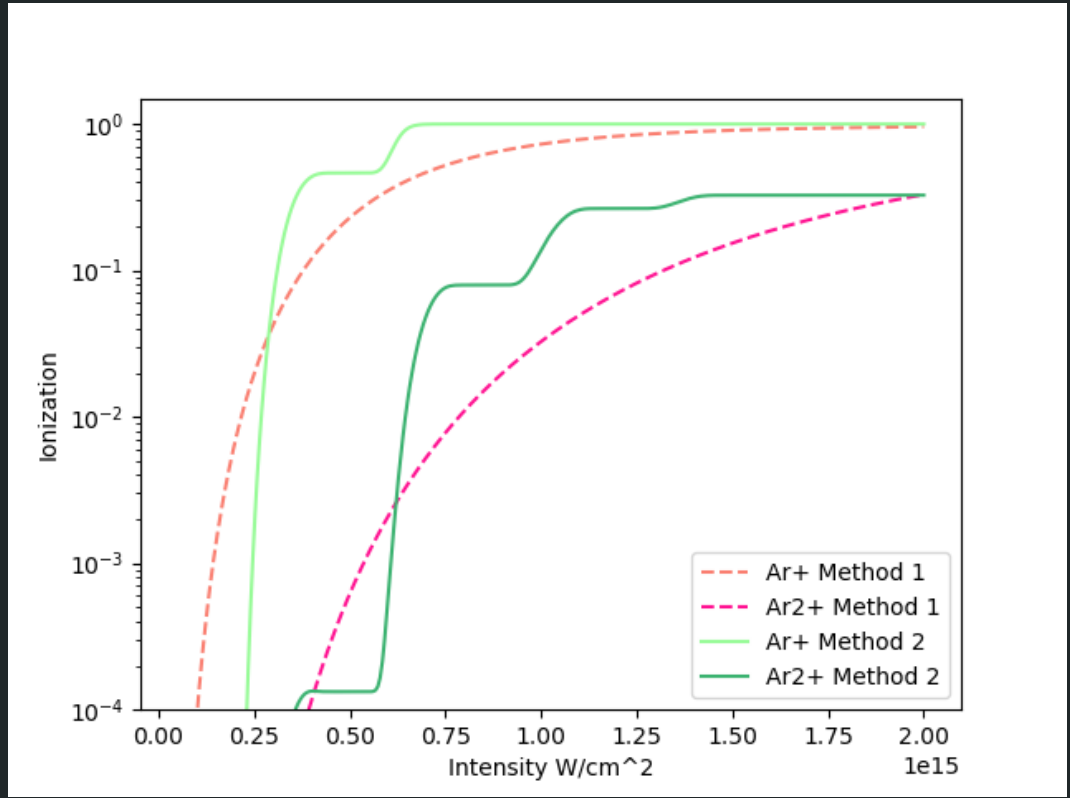
$$P_0 + P_1 + P_2 = 1$$



Lin, C.D., Yuen, I., **Physical Review** 023120 (2022)

Step 3

What happens as we increase the intensity?



Kubel, M. et al. **Physical Review A** 053422-2 (2016)

Finish Line

Goal: Determine probability of ionization given laser pulse parameters

Future Work:

- Determine cause of error in Method 2
- Test other parameters
- Test other elements

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Chi Dong Lin and Isaac Yuen

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