Imaging photodesorption from low temperature O_2 ice

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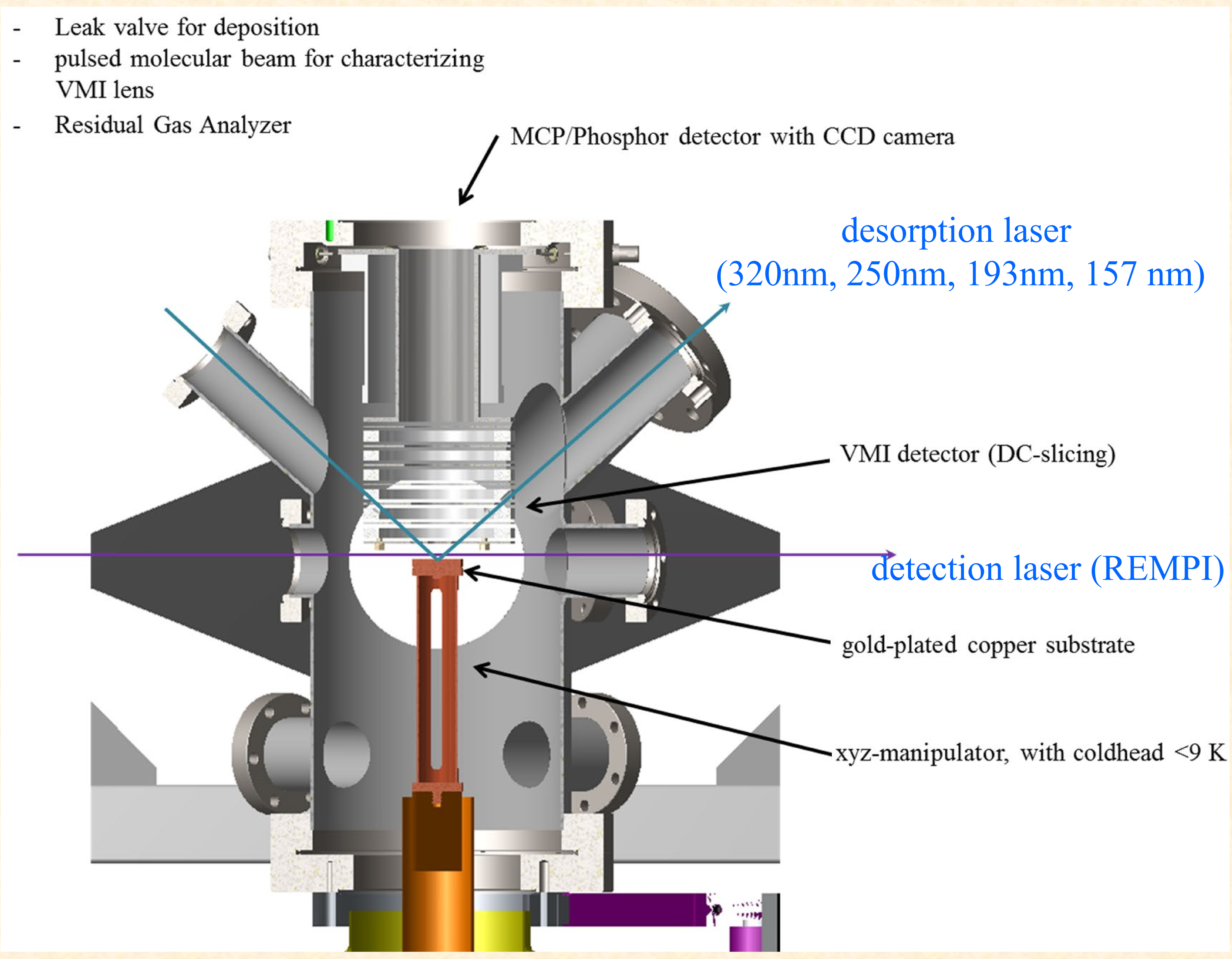
Abstract

A new mass spectrometry method, Atom Fragment Imaging (AFI-MS) provides for the first time both kinetic and internal energy data on mass selected photodesorption O atom products from molecular O_2 ice at 20K. Relative O : O_2 desorption yields found here are consistent with previous studies with the added surprise that a large fraction of the O_2 product is in the excited electronic states (a $^1\Delta_g$, A' $^3\Delta_u$) instead of the $X\,^3\Sigma_g^-$ ground state. In addition, ozone is ejected from surface with VUV desorption.

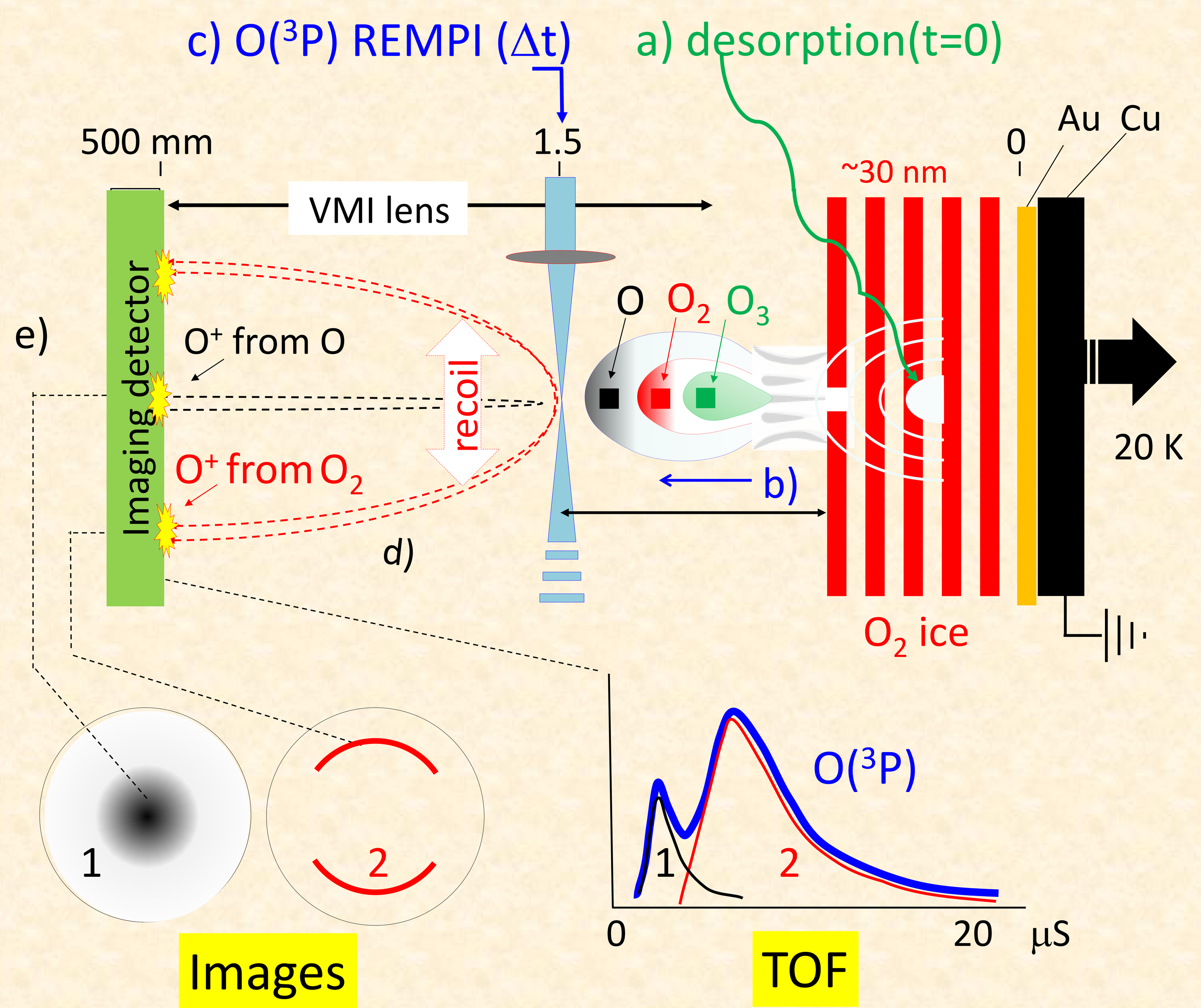
Motivation

In cold interstellar space (T=10-100 K) there is too much gas than expected; it may originates from photodesorption of ice-covered grains. What are the reaction mechanism when cold ice surfaces are exposed to UV/VUV light? In previous studies, REMPI-TOFMS spectroscopy was commonly used, yet only one-dimensional information could be obtained. Here we show that by combining REMPI detection and VMI (Velocity Map Imaging) technique in ice surface study, a new mass spectrometry method, Atom Fragment Imaging (AFI-MS) is developed, delivering rich three-dimensional velocity information to reveal photochemical pathways. O_2 is recently revealed to be the relevant in ISM and O_2 ice is a good starting system.

Experiment setup and Methods

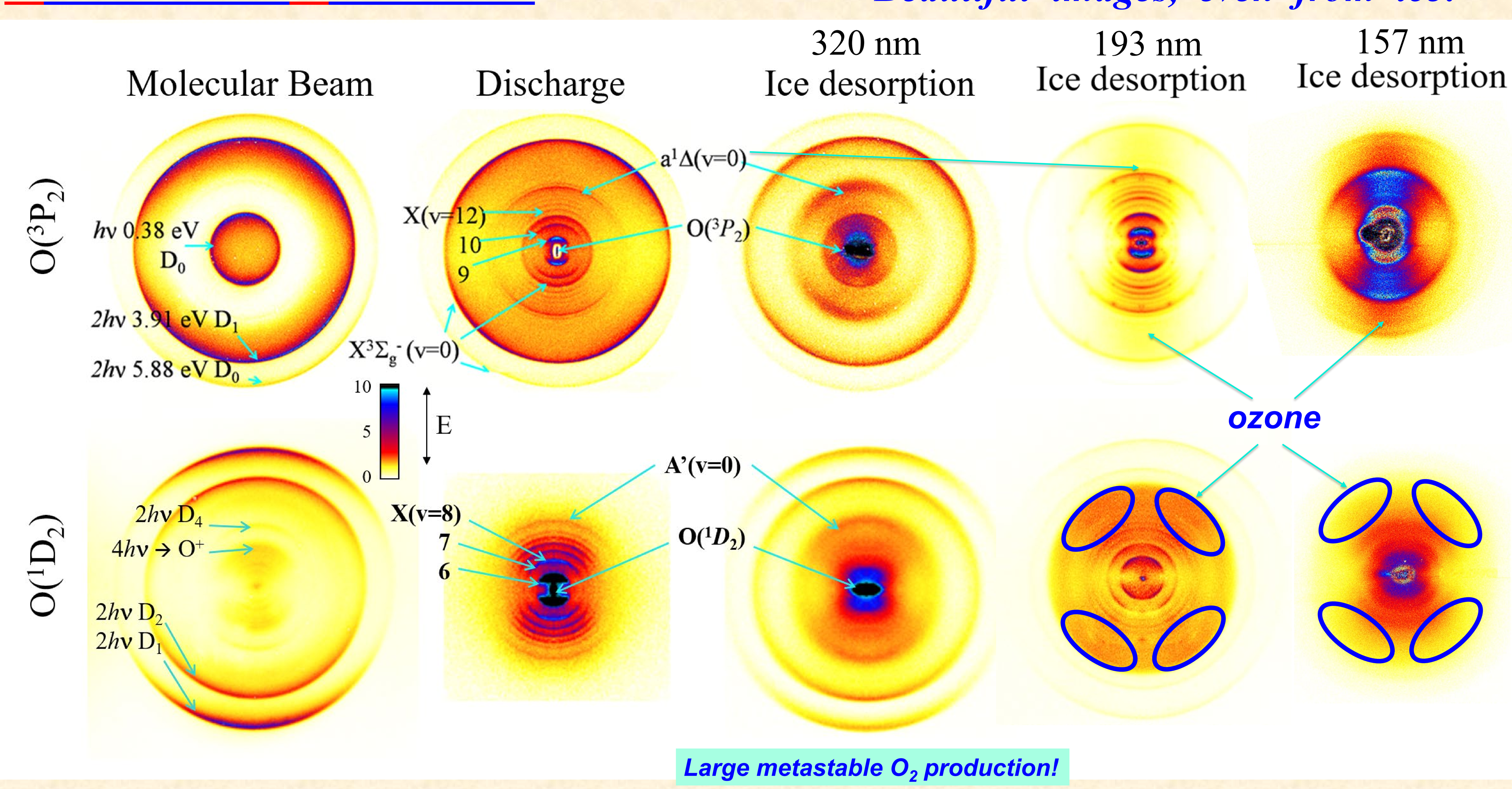


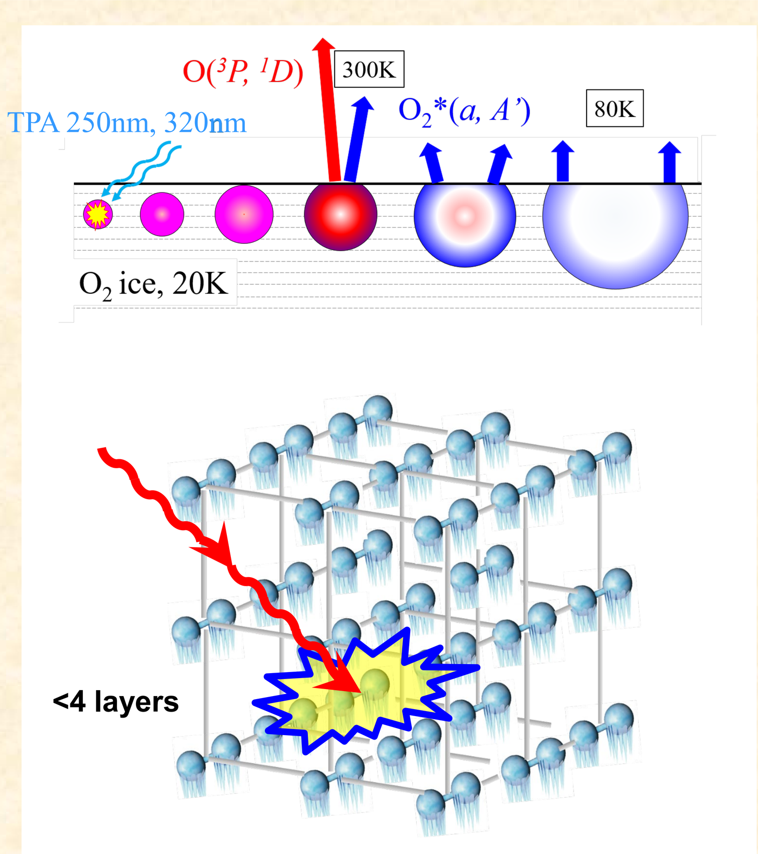
VMI records the recoil pattern for any TOF Δt, showing different origins of $O(^3P)$ atoms



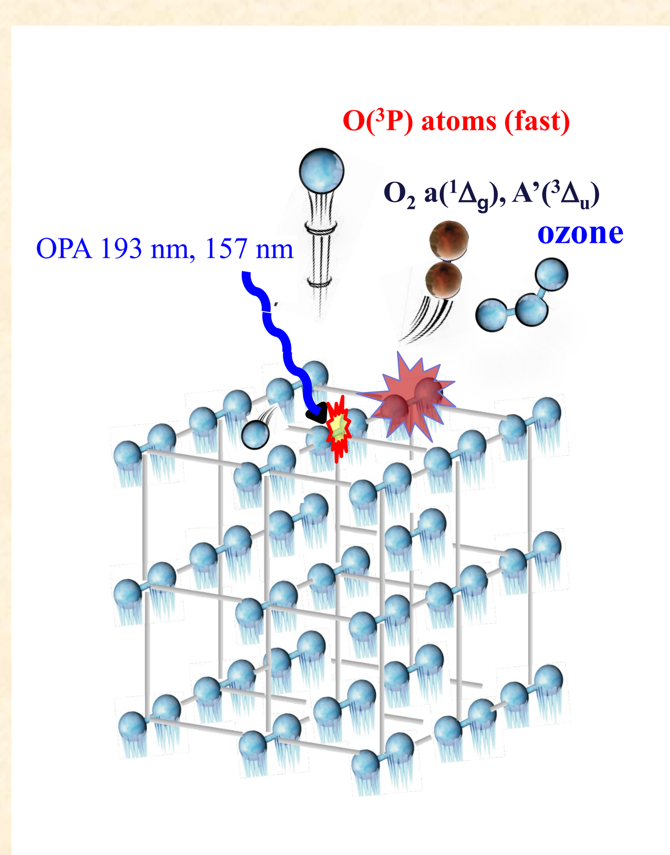
Results and Discussion

Beautiful images, even from ice!





Two-Photon Asorption



One-Photon Asorption

Conclusion

1. Combination of REMPI-VMI with ice is good: high sensitivity, selectivity and information content of REMPI-VMI is proven for ice surfaces by giving nice images;

2. VMI can greatly enhance TOF-MS because imaging pattern helps identify clearly the molecular precursors of O-atom signals, i.e, to reveal photochemical pathways on surfaces;

3. With UV light irradiation, Two-Photon Asorption (TPA) is necessarily taking place; with VUV light, One-Photon Asorption (OPA) takes place. Based on the characterizing measurements of O_2-Rare gas mixed ice, the TPA cross section of O_2 ice is estimated to unexpectedly large;

4. With UV desorption, the primary process is O_2 photodissociation together with recombination of O atoms to produce energetic O atoms and O_2 metastable molecules, respectively; similarity between discharge in O_2 and photodesorptionof O_2 ice suggests recombination is important;

5. TPA occurs below the top surface, thus ground-state O_2 is largely made due to "Kick-off" mechanism with UV desorption. However OPA is effective at the surface with VUV light, giving higher probability of recombination between O and O_2, leading to ozone ejection. And geminate recombination of two O atoms is more likely to generate highly vibrational O_2 molecular products.

Acknowledgement:

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