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► **To cite this version:**

François Vurpillot, S Nulli, Raphaële Danoix, T Prosa, Y Chen, et al.. A Model to Optimize the Voltage Plus Laser Pulsing Mode in APT. M&M2024, Jul 2024, Cleveland, United States. <10.1093/mam/ozae044.030>. <hal-04734940>

HAL Id: hal-04734940

<https://normandie-univ.hal.science/hal-04734940v1>

Submitted on 17 Oct 2024

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Meeting-report

A Model to Optimize the Voltage Plus Laser Pulsing Mode in APT

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One of the notable innovations of the new Leap 6000TM XR is the introduction of a synchronous Voltage plus Laser mode (VpL mode). This evaporation mode triggers the field evaporation of surface atoms by superimposing a laser pulse with a voltage pulse on the specimen. The idea of using the combined effect of laser and electric pulses was initially developed with the aim of measuring the thermal effect induced by the laser [1-3]. However, some benefits exist in using this idea in the purpose to improve APT analysis [4]. Some exploratory tests showed the capability to increase the mass spectrometry performance of the instrument at a relatively low cost [5]. This idea was concretized in a commercial instrument (LEAP 6000) recently with benefits in term of signal-to-noise in APT mass spectra in a variety of materials, including aluminum, stainless steel or even non-conductive materials [6, 7]. The improvement in performances were particularly interesting in non-conductive materials, with an improvement of the FWThM mass resolution and a reduction of the mass spectrum noise (increase of the signal-to-noise ratio by one order of magnitude).

In this paper, we present a numerical approach designed to elucidate the acquired results and potentially to enhance the utilization of the VpL mode. The model takes into account various inputs, including the voltage pulse envelope, the thermal pulse estimated from laser excitation, the presence of the reflectron lens, and the physical field evaporation constants specific to the materials under investigation. As depicted in Figure 1, by closely aligning the parameters with the experimental ones (Figure 1b), the model successfully replicates the key features of the mass spectrum shape, which are notably influenced by the synchronization of the voltage and laser pulses (Figure 1a and c). It is important to note that the null delay is positioned at the peak of the voltage pulse. Optimal performance in terms of noise reduction and mass resolution is achieved when the laser pulse is timed at the near-end of the voltage pulse, with a high voltage pulse fraction, consistent with experimental observations. The mass tail resulting from the temperature decay in the specimen is effectively diminished by the electric field drop at the conclusion of the voltage pulse. The presence of artifacts in the mass spectrum, when the delay is not optimal, is identified as a combination of imperfections in the voltage pulse shape, the thermal response of the sample, and the voltage pulse ratio. The consideration of the photoconductive effect, as proposed in [3], is also deemed a crucial parameter. The model opens up possibilities for predicting the optimal voltage pulse shape to achieve superior metrological performance across a broad spectrum of materials [8].

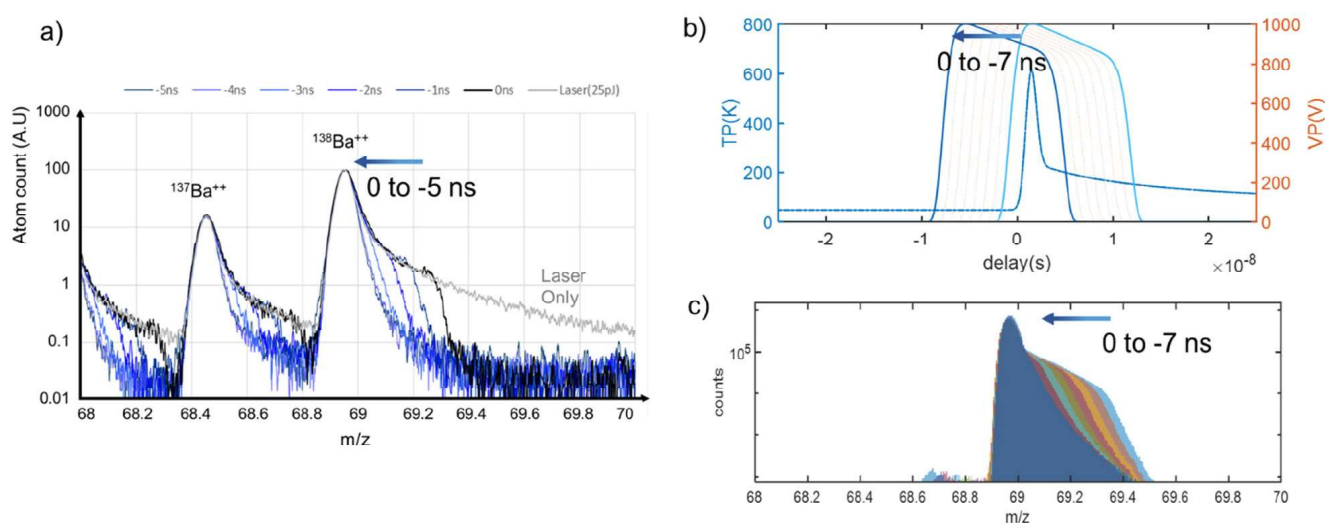


Figure 1. a) Mass spectra obtained on a BaTiO specimen focused on the Ba⁺⁺ peaks ($m/z = 69$) with different delays (0 to -5 ns) between the laser pulse and the voltage pulse b) Modeled voltage pulse shapes with different delays (0 to 7 ns) in orange and modeled temperature pulse in dark blue induced by the laser excitation used to simulate mass spectrum c) resulting simulated mass spectra for Ba⁺⁺ ions ($m/z = 69$) with the different delays (0 to 7 ns).

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8. F.V. acknowledges the support of the French Agence Nationale de la Recherche (ANR), under grant ANR-21-CE42-0024 (project HiKEAP) and the “plan France 2030, PEPR ORIGINS“ under grant ANR-22-EXOR-0008 (project COSMOSAT)