An Evaluation of Wavelengths—
213nm versus 266nm Nd:YAG Lasers

Analytical Forces Driving Deep UV Laser Ablation Developments

The development of 266nm UV laser ablation samplers (Nd:YAG 4th harmonic) resulted in a vast improvement in ablation properties compared to traditional IR Nd:YAG lasers. The improved laser coupling efficiency to matrices due to the shorter wavelength and the smaller crater sizes led to new application areas.

While the 266nm wavelength provides good results on semi-transparent and opaque materials, the coupling efficiency to more challenging, highly transparent matrices, such as calcite, apatite, quartz and feldspars, is still not sufficient for controlled ablation.

Although the ArF excimer laser with a 193nm wavelength shows superior coupling efficiencies to all these matrices, its high costs and use of toxic and decaying gases have hindered its acceptance as a 'routine analytical tool'. These reasons were the driving force behind recent developments of laser samplers based on the 5th harmonic Nd:YAG laser wavelength of 213nm.

The 5th harmonic is advantageous in that it is a derivative of the stable Nd:YAG laser, a well-established routine analytical tool. It yields results from geological materials comparable to 193nm.

Analysis of 'difficult' matrices—Calcite and Apatite

1. Calcite in Geological Applications

One of the pioneer organizations studying the effect of different wavelengths is Memorial University, Newfoundland (Ref. 1). This research continues at various laboratories. The results from the National History Museum, London (Ref. 2) demonstrate the effect of shorter wavelength on coupling efficiency in difficult matrices and are presented here. Figure 1 shows the absorption efficiency for UV laser light in calcite. Significantly improved absorption is achieved at 213nm as compared to 266nm.

As calcite crystallizes with strong cleavage planes, along which it is prone to fracture, the absorption efficiency of the laser wavelength is crucial to the success of producing a well-formed ablation crater. Earlier attempts to use infrared wavelengths to analyze calcite were compromised as ablation led to catastrophic failure. Often, a single laser shot would remove huge mm-size fragments of the sample surface. Even 266nm ablation can lead to fragmenting the sample surface.

A shorter wavelength is preferable to overcome poor absorption of transparent materials as evidenced by the 213nm test results.

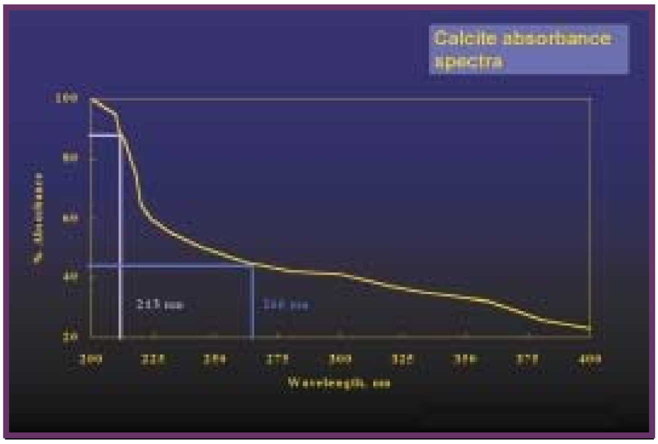

Figure 1. Calcite absorbance spectra.
Courtesy of the Karl Lambrecht Corporation

Figure 1 shows the absorption efficiency for UV laser light in calcite. Significantly improved absorption is achieved at 213nm compared to 266nm.

2. Apatite in Biological Applications

Human teeth consist mainly of an apatite matrix. Since the development of the 213nm laser sampler, the capability to analyze human teeth has improved significantly.

The aim of the study was to compare teeth from ancient and modern individuals in order to determine at what age the person was weaned from milk to solids. Human teeth grow at the rate of 4 microns per day.

Using a laser crater of about 30 microns enables sampling of about a week of growth in the human teeth. The daily increments can be identified easily using the viewing optics of the LUV213.

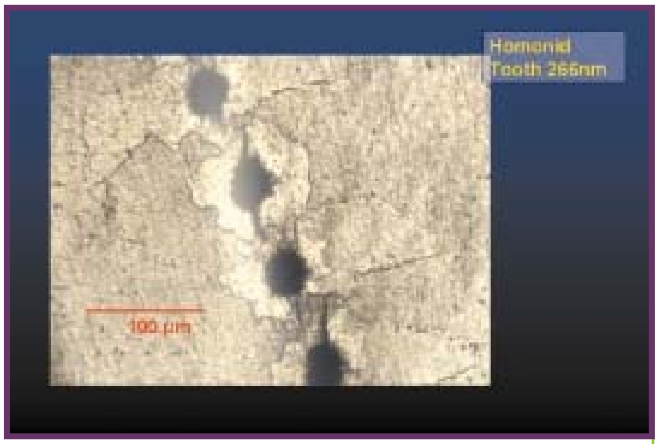

Figure 2. Ablation craters using the LUV266.

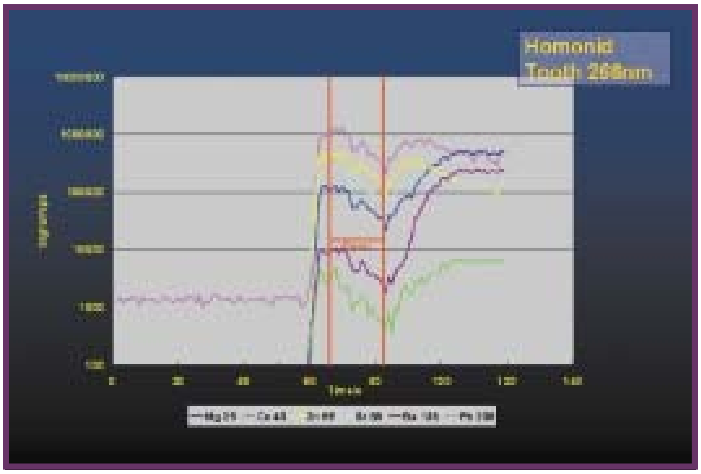

Figure 3. Signal obtained from LUV266.

Figure 5. Signal obtained from LUV213.

Using the LUV266, coupling with the tooth can be achieved (Figure 2), but the signal duration on a single spot is limited (Figure 3).

However, the LUV213 gives not only improved coupling efficiency (Figure 4), but also prolonged and more stable signals (Figure 5). This significantly enhances analytical capabilities.

Using a laser pulse energy of 0.15mJ, a stable ablation of a single site in the thin section lasts in excess of 30s at a repetition rate of 10Hz. The low depth penetration per laser shot enables long ablation times at a single site, sufficient to analyze most elements at low concentrations and to obtain precise isotope ratio data.

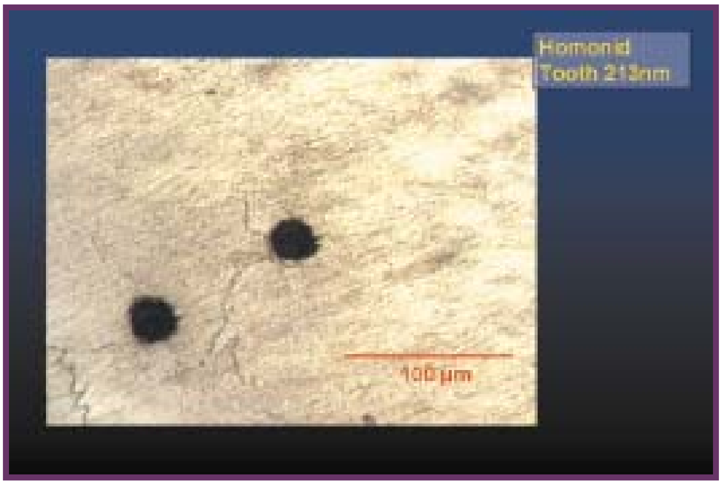

Figure 4. Ablation craters using the LUV213.

Conclusions

The improved coupling efficiency of Nd:YAG 5th harmonic at 213nm offers significant advantages for laser sampling of all geological and biological matrices. Whereas the 266nm wavelength is sufficient for the bulk and feature analysis of materials, such as metals, glasses, polymers, etc., as a routine analysis tool, analyzing many geological and biological matrices present higher challenges.

For the successful analysis of difficult matrices, not only is good absorption efficiency a crucial factor, a long and stable ablation signal duration is required at single sites to perform high quality multi-elemental determinations and precise isotope ratio measurements. The 5th harmonic wavelength at 213nm satisfies these conditions, as does 193nm. In addition, the 213nm laser offers precise depth profile capabilities, due to the long stable signal at a single site, and a better crater profile, leading to improved depth profile resolution.

Acknowledgments

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References

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(2) Jeffries, T.E.: Paper presented at the Winterplasma conference 2001: 213nm laser ablation ICP-MS—revolution or gimmick?

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