Wavelength-dependent absorption and scattering effects on laser cleaning of a corroded iron alloy European scale armor

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Traditionally, the reduction of thick weathering corrosion from historic iron artifacts has been accomplished mechanically or chemically. For some ferrous surfaces, however, these traditional approaches may be too aggressive, prohibitively time-consuming, may jeopardize associated non-metallic materials, or might create an undesired surface appearance. As alternative methods are explored, laser cleaning has become increasingly popular as a conservation tool for reducing corrosion layers from historic metals. In laser cleaning, the laser pulse fluence can be tailored to remove the iron oxides and other undesired surface material without damaging the underlying metal alloy. For some ferrous surfaces, laser cleaning can prove less invasive to the historic artifact and significantly more time efficient than traditional mechanical methods, thereby increasing the amount of surface that can be cleaned within a realistic time frame. After laser cleaning, the metal surface can still be treated using traditional finishing methods to achieve the desired surface aesthetic and to promote corrosion resistance. This research seeks to optimize laser energy profiles for the reduction of ferrous corrosion products on historic iron alloy surfaces. The study examines how the heavily corroded iron alloy surfaces of a 19th century, European scale armor jazeran (19.49.16) in the collection of the Arms and Armor Department at the Metropolitan Museum of Art, New York can be satisfactorily cleaned using a 10 ns, q-switched Nd:Yag laser operating in the second harmonic (532 nm) even when cleaning is unsuccessful operating at 1064 nm. Through the characterization of the various forms of iron corrosion present on the surface, it is shown that the success of the 532 nm laser cleaning is consistent not only with the green laser's more resonant energy absorption but also with the need for this increased absorption due to lower scattering at 1064 nm. The corrosion layers were analysed by stereomicroscopy, SEM/EDS and Raman, directly on a free scale as well as on corrosion scrapings. The stratigraphy of corrosion layers was ~500 µm thick in total consisting of (from metal surface to top): a red layer of platy lepidocrocite (~5 µm in diameter), a dark layer of magnetite, a bright orange layer of acicular goethite (2-3 m in diameter), and a translucent organic film (under analysis). These data were used to optimize the optical parameters of the laser energy interaction with the corrosion products for removal to develop more effective and safer laser cleaning profiles for the reduction of ferrous corrosion layers on the historic iron alloy surface.