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Attogram sensitivity through laser-induced breakdown spectroscopy of single optically-trapped nanoparticles

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ABSTRACT: Current trends in nanoengineering are bringing along new structures for usage over a wide variety of fields: from readily available products, e.g., clothes or foodstuff, to next-generation electronics or drugs. To suit their corresponding application, nanodevices feature increasingly complex chemical compositions, which need to be meticulously defined even at single particle scale to ensure their correct operation as well as to evaluate their potential toxicity. The complete characterization of such exiguous sample quantities demands a great degree of sensitivity met only by few techniques that present drawbacks related to difficult nanoparticles isolation and discrimination of individual-particle events. Thanks to its versatility, laser-induced breakdown spectroscopy (LIBS) offers straightforward simultaneous identification of virtually any kind of sample, hence making it an appealing candidate for single particle analysis, but it is usually hindered by high detection limits. In the present communication, the sensitivity boundaries of LIBS are pushed towards a new extreme as we demonstrate di- rect attogram detection and identification by combining LIBS and optical trapping (OT). In this approach, individual nano- particles are suspended in an optical trap set in air and subsequently probed. Metallic Cu nanoparticles of diameters com- prised between 25 and 70 nm, with masses ranging from 0.073 to 1.61 fg, were steadily trapped under said conditions for the first time. Optical forces acting on the particles were calculated for each sample to assess the stiffness of the trap. A simple classification scheme was developed to discern single Cu particle LIBS events, whose intensities showed linear correlation with particle masses. OT-LIBS showcases a limit of detection of 31 ag for Cu (the mass of a 19 nm particle), unprecedented in optical emission spectroscopy. This sensitivity was linked to more efficient particle dissociation and excitation of smaller size particles in the laser-induced plasma by quantitatively estimating the production of photons per mass unit from recorded spectra. The results described herein should pave the path of LIBS towards the inspection of individual complex nanostruc- tures to the extent of discriminating the presence of undesired trace elements.