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Preface

Lasers and interactions with particles, 2012: Optical particle characterization follow-up

There has been a time when, after the advent of lasers and the subsequent huge development of Laser Doppler Anemometry, those studying electromagnetic scattering became more interested with the development of new laser techniques to simultaneously measure velocities and sizes of particles in flows, from both theoretical and experimental points of view. Sometimes in parallel, but most often later, the other particle properties, such as shapes, temperatures, refractive indices or chemical compositions, became the targets of more new techniques.

Then, it soon became obvious that a series of conferences specifically devoted to these efforts would be welcome. Such a series started in Rouen, 1987, under the title of "Optical particle sizing, theory and practice". It went on under the same title, which was afterward generalized to "Optical Particle Characterization" (OPC), being held in Phoenix, USA, 1990 (organized by D. Hirleman), Yokohama, Japan, 1993 (M. Maeda), Nürnberg, Germany, 1995 (F. Durst), Minneapolis, USA, 1998 (A. Naqwi), Brighton, England, 2001 (A. Jones), Kyoto, Japan, 2004 (M. Itoh), and Graz, Austria, 2007 (O. Glätter). The delay between two successive conferences has usually been three years, but for one case, namely Nürnberg, 1995, adjusted to make the conference coincide with Partec 1995.

When time goes on, things go on as well and develop further. It then eventually appeared that "OPC" was a too much restricted topic, if we wanted to give justice to many new advances, such as the study of internal fields and associated resonances, mechanical effects of light, to name a few. Hence, it has been decided to reformat the conference and to start a new series, actually an OPC follow-up, the ninth of the series, in Rouen, 2012, under the title "Lasers and Interactions with Particles", to be abbreviated as LIP2012, and chaired by G. Gouesbet and G. Gréhan, who started the series, in Rouen, in 1987, 25 years ago. The opportunity has been taken to assemble new committees. The Honorary Committee is essentially made up of people who had been active, and still are active, in the topic, most often having served during the organization of the previous conferences but who, although still very young, are not so young as before. The Scientific Committee, composed of new members, is supposed to take an active part in the preparation of the forthcoming conferences and must feel in charge of pursuing the series whatever would happen. An advisory Committee has been asked to serve to deal with the reviews of the papers submitted to the Journal of Quantitative Spectroscopy and Radiative Transfer, for the present Special Issue. Actually, experts who pertained to the other committees and also who did not pertain to any committee, but should be asked to join the Advisory Committee of the forthcoming conferences, have been very helpful as well, and we cheerfully thank them for their effort.

We also thank the invited speakers who accepted to deliver keynote lectures, namely J.A. Lock who provided novel results for scattering of a focused Neumann beam by a sphere, which has been separately published [1], T. Wriedt who dealt with shaped laser beam light scattering by complex particles using the T-matrix method, B. Pouligny who discussed the issue of optical levitation and long-working distance trapping (from spherical up to high aspect ratio of ellipsoidal particles), and W. Bachalo who, committing himself with light scattering interferometry (invention, development, and application), provided a history of the celebrated phase-Doppler technique to measure simultaneously the velocity and size of individual particles transported in flows, completing and somewhat correcting the previous historical story told by Hirleman [2], 16 years ago.

During LIP2012, 50 papers have been presented. The present special issue compiles 21 of peer-reviewed papers, submitted to JQSRT, providing a significant sample of the contents of the conference presentations. They are introduced and discussed below in such a way that this preface also possesses the flavour of a kind of mini-review, providing the reader with an accurate enough landscape of what is currently going on concerning interactions between laser beams and particles, although some bias is implied by the limited expertise of the authors.

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The simplest kind of laser beams is provided by the class of Gaussian beams, or beams in the TEM_{00} mode. Although any physicist might believe that he/she is familiar with the meaning of "Gaussian beam", there are actually many difficulties and many possibilities for a correct description of such beams. During the development of GLMTs [3], particularly chapter IV, it has become necessary to go beyond paraxial approximations such as for the famous description available from Kogelnik, e.g. [4–6]. Two kinds of description have essentially been considered: (i) Davis beams and (ii) localized beam models. The first kind of description originates from a paper by Davis [7] defining a series of approximations generated by truncating an infinite expansion in terms of a small dimensionless parameter, most often named as beam shape factor or beam confinement factor (or parameter). Only the first-order, third-order and fifth-order approximations are explicitly known [8]. None of these approximations satisfies Maxwell equations (we say that these descriptions are non-Maxwellian) but for the ∞ th-order series. The second kind of description has originally been obtained by applying the principle of localization by Van de Hulst [9] to a first-order Gaussian beam description, although more elaborated and more general descriptions had to depart much from this principle. It takes the form of a localization procedure which may be viewed as a localization operator. When applied to a non-Maxwellian beam, this procedure provides a remodelling of the beam and generates a beam description which exactly satisfies Maxwell's equations (we say that such a description is Maxwellian), see Ref. [10] for a review. For further use, let us also mention that, in GLMTs, incident fields are expanded over a series of basis functions, with expansion coefficients involving sub-coefficients named beam shape coefficients, encoding the shape of the beam. The interest of this introductory paragraph is threefold: it (i) provides some amount of information relevant to several papers presented during LIP21012, (ii) allows one to introduce a lecture discussing a scientific story of GLMTs, supplemented with a few epistemological remarks [11], presented during the last day of the conference and (iii) it serves to introduce the opening talk of the conference which was a keynote lecture by J.A. Lock.

In this context, J.A. Lock discussed the structure of the most generally focused Gaussian laser beam, and its beam shape coefficients for an on-axis configuration, for light scattering applications [12], to order s^4, where "s" is the beam confinement parameter factor. Beam shape coefficients obtained in this framework are compared to those of a localized Gaussian beam model and of the Davis-Barton fifth-order (symmetrized) beam. It has been stated a number of times in the literature that, although localized beam models are based on first-order approximations in the Davis scheme, they anticipate higher-order descriptions. One conclusion of this paper is that it can be claimed that it is instead the Davis-Barton fifth-order beam, as far as light scattering is concerned, that anticipates the results of the localized beam model (in its modified version).

Up to now, most papers on GLMTs have dealt with isotropic particles. Conversely, the next paper by Li et al. [13] dealt with uniaxial anisotropic bispheres illuminated by a Gaussian beam. The theoretical framework relies on a GLMT-approach which is complemented by a generalized multiparticle Mie-solution (GMM), and is originally devoted to plane wave illuminations. Beam shape coefficients are expressed by using a localized Gaussian beam model, and various results are provided exhibiting the influence of beam widths, beam center position, and sphere separation distance on the angular distributions of radar cross-sections. Another issue while dealing with laser beam illumination concerns the normalization of the beam power. This issue is discussed by Stout et al. [14] who presented a semi-analytical theory for calculating light–particle interactions in shaped beams even when the paraxial beam description is not valid. This theory requires weighing the expressions for the cross-sections with a beam normalization parameter associated with the incident power. An analytical formula for this parameter in terms of beam shape coefficients is derived and discussed. This normalization issue is indeed trivial in the case of plane wave illumination but may become tricky in the case of shaped beam illumination, e.g. Section III.13 in [3], particularly in the case of high numerical aperture optical applications.

With the next paper, we begin to discuss internal fields. Han et al. [15] dealt with a GLMT devoted to spheroidal particles in the case of an on-axis Gaussian beam illumination, and a particular attention is paid to the investigation of internal and near-surface fields. Validations of GLMT results are provided from comparisons with the special case of spherical particles, and with the theory of moments. These results concerned the spatial distributions of internal and near-surface fields. The computer program used is written with MATLAB. Localized high-intensity beams called photonic jets (produced by a lens focusing effect) are exhibited in the case of oblate spheroids (although this fact is not explicitly commented). The issue of photonic jets is afterward explicitly discussed by Geints et al. [16] dealing with photonic jet shaping of mesoscale dielectric spherical particles, both for resonant and non-resonant configurations. One of the aims addressed in this paper is to catalogue the jet shapes and to partition them into several morphological groups, having in mind the fact that different applications (optical nano-sensing, laser surgery, contact perforation of cell membranes, etc.) require different types of photonic jets. A first dichotomy is introduced distinguishing the flare- and the dagger-types, these two jet classes being afterward supplemented by considering various other attributes, allowing to propose a photonic jet classification. Although this paper was concerned with plane wave illumination, there would be an interest to extend this work on photonic jets in the case of laser beam illumination, for large enough particles.

We now proceed with internal fields but exhibit a complementary point of view, viz., although Gaussian beams are the most familiar kind of beams, other kinds of beams may be used such as laser sheets, or top-hat beams. With the paper by Zambrana-Puyalto and Molina-Terriza [17], we turn our attention to Laguerre-Gaussian beams. One interesting feature of such beams is that they