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Book reviews

Les Autotransformées Finies de Hankel et Leur Application à l'Hyperresolution

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[pp. i–xx+801, with 86 Figs.]

Quality of an image formed by an optical system, as it is well known, is closely related to the shape of a point spread function characterizing the system. If the aberrations do not occur, this function depends in a simple way on the geometry of the optical system. By inserting an apodizing filter the point spread function can be modified in a wide range. Using this practice known already for years, it is possible to change the imaging characteristic in the way intended by an optics designer. However, a construction of the apodizing filter necessary for obtaining the desired effect is still a difficult task.

In particular, it is of interest to conduct the search of a filter which would narrow the point spread function with respect to its aberration-free equivalent and lead to the increased resolution exceeding the resolving power determined for the analogical aberration-free optical system. Such a problem of superresolution for the optical system of rotational symmetry requires that the integral equation of the Fredholm type be solved in order to find the finite Hankel self-transforms of zero-order. This is dealt with in the book by Richard Boivin.

This extensive monograph (being, by the way, his doctor's thesis) consists of an introduction and two essential parts. In the initial chapter one can find an introduction to the superresolution problem as well as the comments to the papers substantial in this field (e.g., of Frieden and Toraldo di Francia). The first principal part of the book, constituting a little more than a one half of the book, can be called a mathematical one. The mathematical properties of the finite Hankel self-transforms, introduced as the solutions of the differential Sturm-Liouville equation, as well as the computational methods used in this field, are very widely and precisely discussed. The finite Hankel self-transforms have an interesting property, they do not change during Fourier transformation on the circle of the finite radius. For this reason they can be useful in investigations of many problems in such fields as acoustics, telecommunications or just optics. Their application was, however, rather difficult because of essential troubles occurring in their calculations. These difficulties can be at last overcome with help of the reviewed book.

The presentation of the fundamental definitions and relations connected with the Sturm-Liouville equation is followed by the properties of the finite Hankel transforms which are discussed with the special regard to their limiting behaviour. Next, the series expansions of these autotransforms, i.e., the classic (in terms of the orthogonal polynomials), as well as the other ones (seeming to be even more simple) introduced by the author himself, are given. An important part of the book is devoted to the computational methods used for the evaluation of the eigenvalues of the Sturm-Liouville operator which are necessary for the autotransforms' calculation. The computational methods based on the calculus of variations are presented. The latter procedure gives the approximate values of the eigenvalues, while the iterative one enables their correction. Numerical results, which allow the reader to utilize in practice the finite Hankel self-transforms, are presented in tables and graphs. The tables of the expansion coefficients as well as the eigenvalues calculated with high accuracy are very likely published for the first time.

The application of the self-transforms in optics is a subject of the second part of the book. The author discusses precisely the problem of superresolution for the case of the imaging of extended object of limited field in an optical system of radial symmetry. To this end the author constructed an apodizing impulse filter of the Frieden type using the finite Hankel self-transforms. Such a filter generates in limit a point impulse response of the Dirac delta type, even for the finite aperture of the imaging system. The effects of the filter parameters on imaging quality characteristics such as the encircled energy or Strehl ratio are presented. The iterative procedure next employed for the filter optimization makes it possible to achieve the beforehand assumed shape of the point spread function.

Many appendices concerning different mathematical problems connected with the subject matter of the book contain: proofs, examples of some preperties and relations, etc.

It seems that the theory of finite Hankel self-transforms can be successfully applied to optics. It is a very useful tool in the analysis of the imaging quality and, in particular, in designing of the optical filters. The reviewed book contains not only ready solutions of the above problems, but is also a very exact itinerary on the difficult way of the self-transforms' calculations. Its careful study enables the reader to master the practical usage of this tool. It is worth to emphasize that all calculations are conducted very rigorously; there are no such phrases as: "it can be shown that ..." or "it is easy to notice that ..." which in some books cover up the mathematical shortcomings. Although, owing to such an accuracy, the volume of the book increased substantially, but it surely will satisfy the readers who appreciate precision.

The reviewed book seems to be very useful both for mathematicians and opticians to whom it offers a new, but already tested tool.

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Laser Spectroscopy VII

Eds. T. W. Hänsch and Y. R. Shen

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[pp. i–xv+419, with 298 Figs.]

The Seventh International Conference on Laser Spectroscopy was held at the Maui Surf Hotel, Hawaii, USA, June 24–28, 1985. 223 participants represented 19 countries including Australia, Canada, China, Denmark, Finland, France, West Germany, Great Britain, Israel, Italy, Japan, South Korea, The

Netherlands, New Zealand, Poland, Spain, Sweden, Switzerland and USA. The busy program included 14 topical sessions with 59 invited talks as well as about 80 poster presentations.

The conference proceedings published by the Springer–Verlag under the title *Laser Spectroscopy VII* contain abstracts of almost all these contributions. The topics cover a wide range of interests, from basic physical principles as studied by the laser spectroscopic techniques to various applications of laser spectroscopy.

Very interesting reports are contained in the chapter on *Laser cooling, trapping and manipulation of atoms and ions*. MIGDALL et al. describe the procedure of magnetic trapping sodium atoms. The atoms from a thermal source are first precooled from 1000 m/s to ca 100 m/s using a near-resonant circularly polarized counter-propagating laser beam inside a tapered solenoid whose spatially varying Zeeman shift compensates for the changing Doppler shift of slowing down atoms. The 100 m/s atoms are selected by rapid shutoff of both the laser light and the atomic beam after a selected delay. They are then brought to a stop by a short pulse of light from the laser, and the magnetic trap consisting of two coils is turned on. The authors claim to have obtained atoms cooled down to less than 17 mK which is comparable to the lowest energies obtained for laser-cooled trapped ions. CHU et al. report on cooling and three-dimensional confinement of atoms by resonance radiation pressure. The authors use six confining laser beams to obtain a cloud of sodium atoms defined by the region where the beams intersect one another. The calculated temperature of the atoms is about 240 μK and the confinement time is in excess of 0.1 s. The same authors propose another optical method which would enable them to obtain the temperature as low as 1 μK!

WATTS and WIEMAN describe stopping a beam of Cs atoms by means of inexpensive diode lasers which are frequency swept using an appropriate voltage ramp to adjust the frequency to the Doppler shift of the slowing down atoms. This simple scheme allows one to obtain temperature of 1 K.

Laser spectroscopy is known to provide a precise tool for verifying the accuracy of basic physical laws and obtaining values of important physical constants. The paper by KAIVOLA et al. is an example of such a use of laser techniques. The authors undertook a study on the relativistic Doppler shift by measuring the beat frequency between two cw dye lasers, one stabilized to a fast neon beam two-photon absorption (TPA) resonance and the other to the same TPA transition in a thermal sample in a cell. The accuracy of the determination of the relativistic time-dilation effect was ca 4×10^{-5}.

Molecular and ionic spectroscopy has achieved better resolution and sensitivity due to the use of laser techniques. An example of such achievements is the paper by BORDÉ et al. who discuss their progress in revealing superfine and hyperfine structures of infrared spectra of simple molecules. The group uses a 10 μm saturation spectrometer to study molecules whose fundamental bands are located within the usable spectral range. Examples of spectra of OsO_4, NH_3 and PF_5 are presented.

Many papers describe research on new sources of coherent radiation, especially in the vacuum ultraviolet and the X-ray ranges. SILFVAST et al. report on the use of soft X-rays emmitted from a laser-produced plasma to detect autoionizing states of Cd^+. STOICHEFF et al. discuss sources of VUV and XUV radiation tunable to 90 nm. They make use of four-wave sum mixing with two-photon resonance enhancement in vapours of Mg, Zn and Hg. Two pulsed dye lasers (pumped by N_2, KrF or XeCl lasers) are used: one of them (ν_1) is tuned to a 2-photon allowed resonance of the vapour, while the other (ν_2) is tunable over a broad frequency range, so that $2\nu_1 + \nu_2$ corresponds to an autoionizing resonance. The authors obtained 5 ns pulses of coherent light with 10^6 to 10^{11} photons/pulse and linewidths of 0.1–0.5 cm^{-1}. Other types of nonlinear processes (e.g., frequency tripling) have also been used by other authors.

Two interesting Raman spectroscopy techniques are described in papers by ESHERICH et al. and by ORR et al. The former paper presents the technique of ionization-detected stimulated Raman spectroscopy (IDSRS). The technique involves three sequential steps. In the first step molecules are vibrationally excited via resonantly pumped stimulated Raman transitions and in the second they are selectively ionized by a tunable UV source. In the final step the ionized species are collected by biased electrodes where they are detected as current in the external circuit. Raman spectra are obtained by scanning the frequency of one of the Raman pump sources and monitoring the ionization signal as a function of the frequency difference (Stokes shift) between this laser and the second, fixed-frequency visible pump laser. ORR et al., on the other hand, prepare vibrationally excited molecules according to the same scheme, but they use a third laser for a further excitation of the molecules to a fluorescing rather than autoionized state. Fluorescence is then used for detecting the molecules. The authors claim ca. 1000--fold enhancement of Raman spectroscopic sensitivity relative to that of, e.g., CARS or stimulated Raman gain (SRG) spectroscopy.

A few papers deal with the phenomenon of second harmonic generation (SHG) at surfaces and interfaces. SHG is well known to be a property of non-centrosymmetric media, crystals of KDP or quartz being the textbook examples, but can also occur at interfaces of centrosymmetric substances due to local symmetry lowering. Raising et al. studied this phenomenon at interfaces between air and liquids containing layers of surfactants. Heinz et al. use the same technique to study the surface of silicon wafers. A noteworthy paper by Boyd et al. is entitled *Second Harmonic Generation from Sub-Monolayer Molecular Adsorbates Using a CW Diode Laser – Maui Surface Experiment*. The authors show that the surface SHG can be detected using a simple 20 mW CW diode laser. The signal investigated comes from pyridine adsorbed at Ag electrode and is detected with a photomultiplier. The experiment was demonstrated at the conference site: the Maui Surf Hotel in Hawaii, proving the feasibility of SHG surface studies using inexpensive research tools.

As comes from the paper of Byer et al., diode lasers may be used for effective pumping of compact solid state lasers, e.g., an Nd:YAG miniature oscillator. It is also interesting to see that self-frequency doubling may be used for direct obtaining second harmonic output from nonlinear laser media. The authors describe an experiment in which an $Nd:MgO:LiNbO_3$ crystal was pumped by a diode laser and the second harmonic output could be obtained with the threshold pumping power as low as 10 mW.

These are but a few examples of interesting papers contained in the book *Laser Spectroscopy VII*. To summarize this review it is sufficient to say that the book may be highly recommended to all laser spectroscopists as the concise report of recent activities in the field.

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