COST Meeting

30\textsuperscript{th} of March
until
2\textsuperscript{nd} of April
2006

Eindhoven – Mierlo
Local Organising Committee:

- Mark Beks
- Wouter Brok
- Katia Iordanova
- Hjalmar Mulders
- Joost van der Mullen (Chair)

We like to thank our sponsors:

- COST
- Philips Central Development Lighting (CDL)
- Eindhoven University of Technology (TU/e)
- Centre for plasma physics and radiation technology (CPS)
COST Meeting

30\textsuperscript{th} of March
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Eindhoven – Mierlo
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## Program

**Thursday 30-03-2006**

Social get together in Carlson de Brug in Mierlo in the evening.

**Friday 31-03-2006**

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<td>Ignition studies of low-pressure discharge lamps (Maxime Gendre)</td>
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<td>1000-1030</td>
<td>Effect of the source function approximations on the emission intensity of optically thick plasmas (D. Karabourniotis)</td>
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<td>The one-parameter model for temperature determination from self-reversed lines (H. Schneidenbach)</td>
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<td>Why do we use thoriated tungsten electrodes in metal halide lamps? (L. Bartha)</td>
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<td>Dynamic mode changes of cathodic arc attachment in mercury discharges (M. Kettlitz)</td>
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<td>Development of a consistent kinetic plasma model for the ionization layer in HID lamps using Hermite polynomials/Burnett functions (F.H. Scharf)</td>
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<td>Calculation of mobilities of ions in high electric fields under conditions of HID lamps (P. Almeida)</td>
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<td>1500-1530</td>
<td>Conductivity model of discharge lamps, influence of work position on discharge behaviour (A. Richter)</td>
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<td>Short demonstration of our on-line tool for modeling of lamp cathodes (M. Benilov)</td>
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<td>‘Plasimo’ in Theory and Practice... and in the Classroom! (J. van Dijk)</td>
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<td><strong>1800-2000</strong></td>
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<td>2000-2200</td>
<td>Discussion on E-learning (Session leader David Wharmby) The aim of this discussion is to determine how E-learning can be used to stimulate the cooperation of the European research groups on lighting in order to advance the goals of the Lisbon conference.</td>
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**Saturday 01-04-2006**

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<td>3D modelling of DC current transfer to lamp cathodes (M. Benilov)</td>
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<td>0940-1010</td>
<td>The arc attachment at HID-anodes: measurements and interpretation (J. Mentel)</td>
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<td>1010-1030</td>
<td>A method of enhancing the output of a high-harmonics Extreme Ultra Violet source (B. Broks)</td>
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<td>1050-1120</td>
<td>Diffusion of Elements in the MH-lamp (A. Hartgers, M. Beks)</td>
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<td>1120-1150</td>
<td>A Versatile Test Bench for HID Lamps (P. Tant)</td>
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<td>1515-1700</td>
<td>Excursion Historical Philips factory</td>
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<td>Preliminary experimental results on the QL-lamp fed by 2.45 GHz microwave power (A. Gamero)</td>
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<td>1025-1050</td>
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<td>1115-1145</td>
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<td>1210-1235</td>
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<td>1235-1400</td>
<td>Lunch</td>
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<tr>
<td>1400-1530</td>
<td>Management meeting</td>
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<td></td>
<td>This part of the MC meeting will be a &quot;round the table and brainstorming session&quot; animated by David Wharmby on &quot;research for lighting industry?&quot;. With &quot;kickoff&quot;speakers: D. Wharmby, M. Haverlag, Z. Toth and S. Mucklejohn. This will give us ideas about the next COST action.</td>
</tr>
<tr>
<td>1530-1600</td>
<td>Health break</td>
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Announcements

Diner and lunch

Those participants **not** staying in the hotel are required to obtain vouchers from the organising committee for the lunch and/or diner. These will be available in the first coffee break of every day.

Participants staying in the hotel should book their lunch and diner on their hotel room number. The bill needs to be paid when checking out. To do this they need to carry their room keycard at all times.

Badges

It is compulsory to wear the conference badges at all times.

Taxi

If you want a taxi to bring you to Amsterdam Schiphol Airport, you need to report this to the organising committee **before** lunch on Friday. Only then we can arrange a taxi for you for a mere €46.
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Maps

Map of Eindhoven
Map of Historical Factory Area
Map of Hotel Surroundings
Active and Passive Spectroscopy of MH lamps from zero to hyper-gravity

Tanya Nimalasuriya

The wish for compact high-intensity light sources with high luminous efficacy and good colour rendering properties has lead to the development of the metal-halide lamp. This type of arc lamp contains a buffer gas of Hg and a relatively small amount of a mixture of additives such as DyI$_3$, CeI$_3$ or NaI salts, which supply the prime radiators. Because of diffusive and convective processes these additives are non-uniformly distributed over the lamp, resulting in the undesirable segregation of colours. The lamp has been studied with numerous diagnostic techniques. Presented here are x-ray induced fluorescence (XRF) measurements and optical emission spectroscopy (OES) measurements.

XRF measurements have been done at the Advanced Photon Source at Argonne National Laboratory in collaboration with John Curry and Craig Sansonetti of NIST in the United States in February 2005. This method gave very good results when measuring elemental densities of Dysprosium and Mercury. The Dysprosium density is found to be around $10^{22}$ m$^{-3}$ and is comparable to what is found using Laser Absorption Spectroscopy measurements (ground state of Dysprosium) done by Arjan Flikweert. The Mercury density profiles lead to temperature profiles. The temperature profiles are comparable in shape and magnitude to what is found using X-ray absorption as was done by Xiaoyan Zhu.

The OES measurements were performed during gravity conditions varying from zero to hyper-gravity. The emission spectroscopy setup used for the 0g measurements contains an Echelle grating and different filters for wavelength selection. The cross-section of the burner is projected onto the grating after wavelength selection. After wavelength separation by the grating the image is being imaged onto the CCD camera. The image of the CCD camera yields a cross section of the burner in vertical scale and in the horizontal scale the wavelength. Relative atomic and ionic radial density profiles were constructed for lamps containing 10 mg of Hg and 4 mg of Dy.

Radial density profiles of Dy show a clear separation between atomic and ionic regions in the plasma; the ionic region is in the hot centre, the atomic region surrounds it. The radial temperature profiles were constructed from the lateral profile of atomic Hg for different lamp powers. A lamp containing a pure Hg dose, operated at 150W, showed a temperature of 5800 K and a parabolic profile in the centre of the arc. The temperature profile of a lamp containing both Hg and Dy had a temperature of 6200 K (at 150W) at the axis of the lamp, in addition it showed a contracted profile, especially for higher powers.
Comparison between 0-g and 1-g showed that there was more radial segregation at 0-g. The temperature profile of a lamp containing both Hg and Dy at 1g showed an axis temperature of 6200K for 150W.

A centrifuge was built by A.J. Flikweert. The centrifuge has a diameter of 3 m and can go up to 10 g. A similar version of the setup used for the 0-g measurements was mounted onto the centrifuge, enabling us to do emission spectroscopy measurements for 1 to 10g. Atomic density profiles show that at higher g, Dy reaches the top of the lamp, which means the axial segregation decreases. Currently, measurements of the temperature profile and atomic and ionic density profile as function of g for different powers and different pressures are being processed.

At normal gravity conditions, absolute line intensity (ALI) measurements were done using a Jobin-Yvon 1-meter monochromator, to determine radial density profiles. From the radial density profiles, radially resolved Atomic State Distribution Functions were constructed. Axis temperature of 5900K were found for a lamp burning at 100W.
Ignition studies of low-pressure discharge lamps

M.F. Gendre¹, M. Haverlag¹,², H.C.M. Van Den Nieuwenhuizen², J.W.A.M. Gielen², G.W.M. Kroesen¹

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1. Introduction

In past decades, compact fluorescent lamps (CFLs) became available as a replacement for the less efficient incandescent lamps. This breakthrough was made possible thanks to the improvement of fluorescent lamps in general and of the power supplies in particular. Today, further improvements of CFLs require a better knowledge of the physical processes underlying their working principles. One of the key points concerns ignition, as one of their limitations lies in the high-voltage pulses needed for the lamp to start. Although the Townsend mechanism of electron avalanche is a well known model of electrical breakdown, its idealized description cannot be applied to fluorescent lamps and low-pressure discharge tubes in general. Therefore, an experimental research is carried out in order to extend our understanding of the mechanisms occurring during the dielectric-to-plasma transition occurring in low-pressure discharge tubes during ignition.

2. Experiments

The study of the fundamental breakdown processes was carried out with linear lamps (15 cm long, 10 mm diameter) of different fillings (rare gases and mercury vapor) at pressures ranging from 2 to 10 mbar. Their design is identical to the discharge tubes employed in CFLs, except that a straight geometry is employed and that no fluorescent powder is present.

Negative and positive square voltage pulses as well as alternating voltages ranging from 50 V to 1200 V were applied to one of the lamp electrodes (the active electrode), while the other one was kept at ground potential. A given lamp was housed inside an electrically grounded and nitrogen-flushed cylindrical Faraday cage that controls the discharge tube environment, thus ensuring that the same initial conditions were met during each experiment.

Three diagnostic tools where employed for the study. Firstly, a fast Intensified Charge Coupled Device camera was used to record the light emission emerging from the lamp with a sub-microsecond time resolution.
Secondly, three micro-current probes monitored the charge flow in different part of the lamp-Faraday cage system. Finally, a novel floating-potential capacitive probe was designed and used to measure the space and time evolution of the surface electrostatic potential of the lamp. The synchronization of these diagnostic tools with the lamp voltage waveform permitted cross comparisons and correlations between different experimental results.

3. Experimental results

Optical diagnostics have shown (figure 2) that in DC-driven linear lamps a localized ionization wave initially starts between the active electrode (at right) and the nearest section of the lamp wall, and propagates toward the opposite electrode (located at left). Comparisons with electrostatic probe data reveal that the propagation of the wave is correlated with that of a potential wave associated with a local region of strong electric field located at the head of the wave. The lag between the peak of electric field and that of light emission ranges from tens of nanoseconds to one microsecond.
Fig. 2: Optical recording (left) shown with steps of 0.5 s and measured equipotentials (right) associated with ignition of an argon lamps (3 Torr) at -400V.

A minimum potential exists below which the first wave fails to reach the opposite electrode. While this know criterion defines the limit between a failed and a successful ignition, data comparisons have shown that another requirement for a successful ignition lies in a minimum amount of charges to be provided to the lamp. If both criteria are met, then the pre-breakdown wave reaches the opposite electrode, starts a current flow across the lamp and initiates a second wave (return strike) that develops in the opposite direction with a higher speed.

Shape and speed evolutions of waves depend on their polarity. Cathode-initiated waves spread and decrease in speed over distance and time (figure 3) while anode-initiated waves have more constant shapes and speeds throughout their propagation. The differences between the two kinds of waves arise from the wave head polarity that sets the electric field direction. While cathode-initiated waves draw electrons from the cathode and eject them ahead of the front, anode-initiated waves pull electrons ahead of the front. This latter mechanism requires photo-ionization processes for the wave to displace itself toward the cathode.

We also found a direct proportionality between the applied voltage and the pre-breakdown wave speed of cathode-initiated waves (figure 3), which suggest a direct linearity between cathode voltage, wave front electric field, ionisation rate and rate of charging of the lamp wall.
Ionization wave speeds are found to be higher in rare gases of lower atomic weights and higher ionization energies (figure 4). This observed trend accounts on the lower momentum-transfer cross-section of light atoms that increases the electron mean energy. This turns out to over-compensate for the higher atom ionization energy and thus raise the ionization rate in the head of the wave front. The wave speeds were found to be the fastest in mixtures of argon and mercury vapor, found in most commercial fluorescent tubes. This observation arises from the Penning ionization mechanism that is efficient at raising the ionization rate.

Fig. 4: Speed (left) and duration (right) of the propagation of the first ionisation wave for argon and krypton as a function of pressure at -600V. Data calculated from optical observations.

4. Conclusion

The simultaneous use of several diagnostic tools was permitted by a careful control of ignition experiments with low-pressure lamps. Comparisons between experimental data revealed the propagations of ionisation waves back and forth in the lamp prior the establishment of a steady-state discharge. This propagation was correlated with that of a localized region of strong electric field whose direction defines the propagation behaviour of the wave.
Impact of the source function approximation on the shape of optically-thick atomic lines

D. Karabourniotis
Department of Physics, Institute of Plasma Physics, University of Crete, Heraklion, Crete, Greece

The theory of the formation of a spectral line emitted from an inhomogeneous plasma layer was reformulated to account for the radial change of the line profile. Readily calculable expressions for the optical depth profile and the spectral line intensity were derived.

The line intensity was calculated assuming a Lorentzian position-dependent line profile due to atomic or electronic collision broadening and using (i) a plasma model based on realistic functions for the radial distributions of the relative densities of the emitting and the absorbing atoms and (ii) a simplified model based on the one-parameter approximation (OPA) for the source function. In the case of the OPA, the source function is described by a simple exponential law, the exponent of which is the inhomogeneity parameter (alpha).

The line emissivity at the peaks of self-reversed lines was then calculated as a function of alpha applying the plasma models (i) and (ii). The results of the two models are in good agreement between them. Their difference is lower than 5%.

In order to investigate the possibility of determining the value of the inhomogeneity parameter, numerical experiments were performed by arbitrarily varying the optical depth keeping constant the alpha-value. The results show that the determination of alpha is possible for relatively low optical depths at the line center on the basis of the OPA.

Surprisingly, experimental results using an absorption method indicate that the value of the optical depth within self-reversed lines (Hg-5461 Å, Tl-5350 Å and Na-D-lines), which are emitted from arc lamps at a pressure of a few atmospheres, is always less than 6 (six).

Further investigation is needed to test the validity of the alpha-determination in case where the optical depth changes as a function of the lateral distance of the considered plasma chord to the arc axis.
The one-parameter model for temperature determination from self-reversed lines

H. Schneidenbach, St. Franke

The applicability of the one-parameter model of Cowan and Dieke to the temperature determination from radiance maxima of self-reversed spectral lines has been proved. In this model the line emissivities at the reversal maxima are completely determined by the so-called inhomogeneity parameter. The determination of this parameter requires additional information which is usually extracted from measurements at the reversal minimum. Different terms are neglected in the framework of the one-parameter approximation in comparison with the exact expressions. The influence of these terms has been analysed by a comparison of the approximations with exact solutions of the radiation transport equation under restriction to LTE conditions.
Why do we use thoriated tungsten cathodes?

I. Gaal, L. Bartha

Thorium may play different roles in light sources, like
- improving the high temperature creep properties of tungsten coils
- influencing the electron emissivity (work function) of the cathodes
- influencing the oxygen activity by interaction with the materials in the lamps

The above functions are demonstrated by experimental results, like
Case 1: High temperature creep curves of different tungsten wires
   Electron emission micrographs on the kinetics of Th release from thoriated tungsten
Case 2: Visualisation of the transport of different metals inside of halogen lamps by autoradiography, using radioactive isotopes. Discussion of the possibility of thorium regeneration from the lamp filling gas onto the cathode surface.
Case 3: Auger analytical and SEES studies on the stability of cathode surfaces under vacuum conditions at high temperatures.
Cathodic arc attachment after a steady state anodic phase is investigated in a vertically operated 0.7 MPa mercury high intensity discharge lamp with pure tungsten electrodes. Experimental evidence of a dynamic mode change of arc attachment influenced by convective effects is documented. Finite element simulation of the temperature field in the cathode body in two and three dimensions is performed. Nonlinear surface heating using Neumann’s and Benilov’s model is employed. The presheath voltage drop as function of electron temperature is proposed as compact input parameter. Both models have the ability to show transient mode changes observed in the experiment. There are strong indications that the transient spot processes a nonzero minimum life time when it abruptly emerges at a distinct threshold. The results are applicable for the design of dimming modes of HID lamps.
Development of a consistent kinetic plasma model for the ionization layer in HID lamps using Hermite polynomials/Burnett functions

F. H. Scharf, R. P. Brinkmann  
Ruhr-Universität Bochum, Lehrstuhl für Theoretische Elektrotechnik, Center for plasma science and technology, 44780 Bochum, Germany

The description of the ionization layer in HID lamps using fluid models bears complications. To describe the physics correctly, various effects such as three body recombination have to be taken into account. However, to keep the mathematical description simple, as many effects as possible are usually neglected. The decision which effect has to be included and which effect can be neglected, is not always obvious and often subject to discussion.

To avoid this, our goal is to develop a consistent kinetic model. From this model, it will be possible to deduce a consistent fluid description as well. In this talk, we will present the geometry of our model, together with a discussion of the collision term we use in Boltzmann’s equation. To solve the equations we obtain, we will use Hermite polynomials – or Burnett functions, for spherical coordinates. We will present some of the properties of these functions. Also, we will discuss the feasibility of using these functions for kinetic modeling, with special focus on orthogonality relations and convergence.

Acknowledgments
The authors would like to thank the Deutsche Forschungsgemeinschaft for the support granted within the Sonderforschungsbereich SFB 591 and the Graduiertenkolleg GK 1051.
Calculation of mobilities of ions in high electric fields under conditions of HID lamps

P. Almeida

The use of the two-temperature displaced distribution theory for the calculation of ion mobilities is illustrated. The advantages of this approach are discussed and the results compared with those given by preceding conventional theories. The ion mobilities calculated in such way are in excellent agreement with experimental data. A FORTRAN program, both as an executable file and in the form of a source code, is freely available online.
Electric conductivity model of discharge lamps

J. Koprnicky, A. Richter, J. Vaclavik

Concept of the work with model? Why do we need electrical model of light discharge? Does universality of the electric conductivity model exist? Does have the conductivity model its own future in practical applications?

Influence of work position on discharge behavior.
Presentation of new experiments.
Tomographic diagnostics of plasma light sources

N. Denisova, G. Revalde, A. Skudra

1 Institute of Theoretical and Applied Mechanics, Novosibirsk, Russia
2 Institute of Atomic Physics and Spectroscopy, University of Latvia, Riga, Latvia

Plasma light sources are usually inhomogeneous objects. A better understanding of physical processes occurring in a plasma and optimization of the light sources performance require knowledge of their spatial properties. Optical diagnostics are performed usually by measurements of integral characteristics. Local characteristics can be derived from the integrated data by combining of an integrating measurement techniques and computer tomography algorithms and methods.

In this work, a tomographic reconstruction of spatial profiles of the mercury atom density in the excited state $^7S_1$ in high-frequency electrodeless lamps (HFELs) has been performed. The measurements of the Hg 546.1nm line emission intensity have been made for the HFELs in argon-mercury mixture in dependence on the operation regime by different cold spot temperatures in the range of $31^\circ C - 98^\circ C$. The Maximum Entropy-based (ME) algorithm was applied for the reconstruction of the local emission coefficients from the integrated intensities. The emission coefficients are directly related to the local values of the mercury atom density in the excited state $^7S_1$, the upper state of the 546.1nm transition. Such an investigation has been performed first for the HFEL.

We have found that the emitting mercury atoms in the state $^7S_1$ are concentrated in a thin layer located close to the lamp wall. The radial profiles have demonstrated a strong depletion of the population density in the state $^7S_1$ from the lamp centre at high generator currents and low mercury vapor density. The obtained results are analyzed theoretically in the context of the radial cataphoresis phenomenon. We found a qualitative agreement between the reconstructed density profiles and theoretical model predictions.
Short demonstration of our on-line tool for modeling of lamp cathodes

M. Benilov

A demonstration will be presented of a code for simulation of the diffuse mode of interaction of a high-pressure plasma with a cylindrical thermionic cathode which is freely available on-line at www.arc_cathode.uma.pt. The code is fast and robust; the database includes a large variety of plasma-producing gases (in particular, inert gases, mercury, metal-halide plasmas). The code is destined to researchers working on high-pressure arc discharges. It can be used for investigation of plasma-cathode interaction; for generation of boundary conditions on the cathode surface for codes simulating the arc plasma; as a part of codes simulating the whole system arc-electrodes.
'Plasimo' in Theory and Practice... and in the Classroom!

J. van Dijk

At Eindhoven University of Technology the plasma modelling toolkit Plasimo is being developed. Once started as a dedicated tool for understanding Inductively Coupled Plasma (ICP), in the last ten years the code has developed into a fully-fledged modelling platform, capable of handling a variety of plasma geometries, modes of electromagnetic power in-coupling and states of equilibrium.

The broad scope of Plasimo requires that sufficient attention is paid to the software engineering aspects of the toolkit. Indeed, modern implementation techniques and state-of-the-art C++ idiom have found its way into the Plasimo source tree.

Crucial to Plasimo's success has been the usage of so-called abstract interfaces. As a result, modules can be developed and tested in isolation, keeping the development process manageable. Another consequence of this design is that the physics modules can be used in a highly context-independent fashion. Perhaps these modules will later be used as add-ons in full plasma calculations. But the components may equally well be used independently, which brings us to a highly underestimated quality of Plasimo: it can serve as a great tool for learning physics!

Engineers may use the full plasma modelling capabilities as a CAD instrument in product development efforts. At the same time, students of physics may study the properties of the Navier-Stokes equation by running the barycentric flow model in isolation. Yet others may study departures from equilibrium, using the model for species diffusion with source terms on a bounded domain. Or study heat transport in a thermally conducting rod.

In this presentation, we will briefly outline the history and present scope of Plasimo. We will then present some possible 'classroom' applications of Plasimo.
Dynamic modeling of discharge lamps based on step response

M. Alvarez

No abstract received.


3D modelling of DC current transfer to lamp cathodes

M. Benilov

Numerical investigation of steady-state interaction of a high-pressure argon plasma with a cylindrical tungsten cathode is reported. A whole ‘zoo’ of very diverse modes of current transfer is revealed. Divergences in the general pattern of solutions, which have been present in preceding works, are resolved. Hypotheses on stability of steady-state solutions, available in the literature, are analyzed. It is found that these hypotheses provide an explanation to the fact that the transition between diffuse and spot modes is difficult to reproduce in the experiment but do not explain indications that it is the low-voltage branch of the first 3D spot mode that seems to occur in the experiment. Thus, the question of stability of steady-state solutions remains open: an accurate stability analysis is required, as well as additional experimental information.
The arc attachment at HID-anodes: measurements and interpretation

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Anodes for HID lamps made of cylindrical tungsten rods and the plasma in front of them are investigated in a special model lamp filled with argon and other noble gases at pressures of $0.1 - 1\text{MPa}$. The arc attachment on these anodes takes place in a constricted mode. The temperature is measured pyrometrically along the electrode axis and the anode fall electrically. The electron temperature $T_e$ and the electron density $n_e$ within the anodic boundary layer are determined spectroscopically with high spatial resolution. It is found that the power input into the anode increases nearly linear with the arc current. The proportionality constant is mainly determined by the work function of the electrode material and $T_e$ but is independent of the electrically measured anode fall and scarcely dependent on the electrode dimensions. The constriction is more pronounced on cold anodes with maxima of $T_e$ and $n_e$ in front of the electrode surface than on hot anodes with thermionic electron emission and vaporization of electrode material. The distances of the $T_e$- and $n_e$-maxima from the anode surface are increased and $T_e$ is reduced in front of the anode with increasing anode temperature. The experimental findings may be explained by a model of the anodic boundary layer consisting of a thin sheath in front of the surface and a more extended constriction zone. Current and voltage are anti parallel within the sheath. The power which is needed to sustain the sheath is supplied by an enhanced electrical power input into the constriction zone.
A method of enhancing the output of a high-harmonics
Extreme Ultra Violet source

B.H.P. Broks, J. van Dijk, J.J.A.M. van der Mullen

High-harmonics generation by the interaction of intense terawatt laser beams with is a proven technique for the generation of Extreme Ultra Violet (EUV), with typical wavelengths of 40 nm. In this process, multiple photons interact with an optical transition in an atom or ion, generating a new photon with an energy that is the sum of the original photons. This process becomes far more efficient when the laser beam is more intense, which can be achieved by focusing it more tightly.

The interaction between the laser and the matter occurs in a waveguide. Such a waveguide is necessary to preclude diffraction and keep the laser focus small. In an evacuated gas waveguide, the interaction between the laser and the wall keeps the laser focused in the center of the channel. In such a waveguide, modulating the radius compresses the laser beam, greatly enhancing the EUV output. Another common type of waveguide is the plasma waveguide, in which a dense plasma with a convex index of refraction pattern is used to focus the laser. In this contribution, we will numerically investigate what the influence of modulating the radius of the plasma waveguide on the plasma, the waveguide wall, and the laser guiding.
A novel method to describe diffusive processes in plasmas in local thermodynamic equilibrium (LTE) was developed, based on the transport of elements instead of individual species. This method combines the elegance of the LTE description of a chemical composition with the flexibility of explicit transport for each element. A simple model of an Metal Halide (MH) lamp containing Hg dosed with NaI is used to illustrate the method.
A Versatile Test Bench for HID Lamps

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The test bench consists of two main components: a general purpose, rapid-prototyping inverter unit as a flexible power source for HID lamps, and a high-voltage test platform to investigate the ignition properties of HID lamps.

This inverter platform, already used in several other applications, consists of four independent half-bridge units, controlled by an Altera FPGA and a TI DSP [1], [2], [3]. Each channel has its own high-speed current measurement circuitry, and is capable of switching frequencies up to 60kHz. In this application, the ability to measure the current in each half-bridge was used to implement hysteretic current control, allowing any arbitrary lamp current to be programmed. The general setup is shown in Fig. 1. Because of the high switching frequency and the high bandwidth of the current control loop, the FPGA performs the hysteretic current control, while the DSP provides the FPGA with a reference current. The power control model running in the DSP is generated using the Matlab Simulink Real Time Workshop, and communicates with the Simulink model on the host computer. This allows parameters to be changed in real time.

A Tesla transformer is used as a flexible platform to investigate the ignition properties of HID lamps. In pulsed mode, the Tesla coil is in a double resonance configuration, based on two magnetically air coupled LC resonating circuits (Fig. 2a) [4]. Capacitor C1 is initially charged to a voltage Vdc through R1. When triggered, thyristor TH discharges capacitor C1 in L4. This results in high frequency burst pulses across C2.
(in the kHz range) with a pulse duration of a few ms. The maximum pulse repetition rate is determined by the value of R1. The burst pulse amplitude is adjustable from 0 to 19kV.

![Diagram of Tesla transformer configurations](image)

*Fig. 2 Tesla transformer configured for double resonance (a) and single resonance (b).*

In continuous mode, the Tesla coil is continuously driven with a square wave voltage at resonance frequency (Fig. 2b). The driver consists of two 600V/20A MOSFETs and two fast recovery diodes. To avoid difficulties with shoot-through and dead-time adjustments at high switching frequencies, an asymmetrical H-bridge circuit is used in the power stage. Both MOSFETs are switched on or off simultaneously. The amplitude of the continuous sine wave output voltage is adjustable from 0 to 15kV. The output frequency depends on the individual values of L3 and C5 in the resonating circuit. When an electrical breakdown in the HID lamp or a short-circuit occurs on the secondary side of the transformer, the resonance disappears. Since the transfer of energy then stops, the output voltage collapses, resulting in a safe operating condition for the HID tube.

References:

Preliminary experimental results on the QL-lamp fed by 2.45 GHz microwave power

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The QL-lamp is a model of discharge lamp free of electrodes developed by Philips available from 1992. This lamp uses the magnetic induction of an EM field at 2.65 MHz of frequency to produce the discharge and it has been widely studied by different methods [1-3].

Our purpose in this preliminary work is the study and characterisation by means of spectroscopic diagnostics of this same system but producing the discharge by using the dissipation of microwaves at 2.45 GHz, what supposes a remarkable difference with respect to the studies carried out previously.

For this purpose, we will analyse the relative intensity of certain emission lines coming from the de-excitation of the species existent in the discharge and their dependence on certain characteristics of the involved atomic levels such as their excitation energy or their effective principal quantum number.

In this work preliminary analysis on radiometric characteristics are also shown, comparing the lamp at 2.45 GHz with the original QL-lamp at 2.65 MHz.
Light related research at the Light source spectroscopy laboratory in Riga

G.Revalde

An insight in light research activities at the High resolution spectroscopy and light source technology laboratory in Riga will be given. The laboratory is a part of the Institute of Atomic Physics and Spectroscopy at the University of Latvia. The laboratory has about 30 years long experience in the low pressure plasma investigation and spectroscopy. Different high resolution spectroscopy methods have been used, such as emission spectroscopy, line shape studies, Zeeman spectroscopy, ion trap spectroscopy etc. Recently, the main interest is devoted to the inductively/capacitatively coupled low-pressure plasmas for different applications. The laboratory has expertise in the electrodeless discharge lamp technology and development for different purposes.
Research on science and technology of light sources in the Centre of Plasma Physics and their Applications of Toulouse (CPAT)

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The "High Intensity Light Sources" team in CPAT is working exclusively on the Science and Technology of Light sources since 1972. The actual team composition consists of five permanent researchers (2 professor, 3 assoc. professors), one technical staff, a post-doc and 5 PhD students. Furthermore since last years this team has a leader position in France for the study of interactions between the electronic-power supply and discharge plasma. We developed special techniques in order to study transitory situations (dimming, start-up…) and lamp ageing.

The team is focussing on the study of HID, fluorescent and DBD lamps. Both modelling and experiment are done in these domains. Furthermore, for fluorescent lamps we developed time dependent collisional-radiative models describing the plasma characteristics, these models can also be integrated in circuit simulation software. For HID lamps (especially MHLs) we work on fluid models on LTE (or near LTE conditions) that we couple with detailed chemical equilibrium inside the plasma. A special attention is given during the last years to acoustic resonance phenomenon. Finally concerning DBDs we developed a kinetic model of the discharge able to describe the filamentary behaviour of the lamp and the coupling of the plasma model with the specific boundary conditions taking into account the presence of dielectrics.

The team has important experience on visible spectroscopy and electrical measurements. We have in Toulous various spectroscopic experimental set-ups for emission and absorption spectroscopy; A fast CCD camera (2 ns aperture time, 20 kHz max sampling frequency); It is also equipped with an industrial pumping set-up for the realization of low-pressure and Dielectric Barrier discharge lamps. This allows the realisation of prototypes under well-controlled environment. For example, during the last months we could produce our own Xe-Cl₂ lamps for medical devices.

Research activities of this team are done in close cooperation with big lighting Industries (Osram, Philips, GE Lighting, Ushio…) and electronic device manufacturers (Schneider Electric, Tridonic…).

For more details on the CPAT see on http://www.cpat.ups-tlse.fr
Activities of the Lithuanian light group

A. Zukauskas

During the years from 2002 to 2006, the activity at Vilnius University on COST action Nr. 529 “Effective lighting in 21st century” was implemented in the field of basic research on materials for advanced semiconductor emitters and niche applications of solid-state lighting.

Materials research was focused on the investigation of the origin of spontaneous and stimulated emission in group-III nitride structures, which are the key components of advanced light-emitting devices for the green to UV region as well as for white solid-state lamps. In particular, dynamics of carrier recombination in AlInGaN structures grown by various and over various substrates was studied using spectroscopic techniques. Also, the inhomogeneous electronic band potential profile in group-III nitride alloys was revealed using Monte Carlo simulation of exciton hopping.

The optimization problem for polychromatic white lamps composed of four and more primary light-emitting diodes (LEDs) was solved. Stability of the polychromatic lamps in respect of variation of the primary-LEDs parameters and junction temperature was analysed. A complementary source of white light consisting of a phosphor-conversion white LED and coloured LEDs was modelled. A computer-controlled quadrichromatic red-amber-green-blue (RAGB) lamp with digital feedback was developed. The stabilized lamp was applied in the investigations of seasonal affective disorder and subjective colour perception.

Solid-state 8-wavelength lighting facility for control of photophysiological processes in plants was developed. Results on increased photosynthetic productivity, improved morphogenesis and enhanced nutritional quality in greenhouse plants were obtained.

Work on applications of advanced LEDs in measurement technology was conducted. A UV-LED based fluorescence sensor for detection of organic compounds was developed. Measurements of Raman spectra using high-power light-emitting diode were performed for the first time. Application of UV LEDs for measurement of fluorescence lifetime in biological compounds using frequency-domain technique was demonstrated.
Research and Education on Lighting Laboratory

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Stuff and facilities
The staff of lighting laboratory consists of two professors, one docent, three postdoctoral researchers, seven post-graduate students, two senior researchers and associate stuff. Lighting Laboratory has a wide range of measurement equipments for light sources and lighting installations measurements, for instance integrating sphere, spectroradiometer, Flash Meter for measurement of rapidly changing illuminances, Goldman Perimeter for vision experiments, goniometer to measure the luminous intensity distributions of narrow beam lights, Luminancephotometers and facilities for lamp tests. We have Glass Research Room designed mainly for daylight research, Dark Room for lighting measurements with full control of external light and an underground Tunnel for Road Lighting Installations (length 200 m).

Teaching
The teaching of Lighting Laboratory is focused on illumination engineering and electrical building services. The teaching areas include vision and lighting, basics of illumination engineering, lighting applications, light sources, lighting calculations and measurements, home and building electronic systems. Six courses are available in English, for instance Illumination Engineering and Electric Installations and Project of Electrical Engineering. There are more than 20 post-graduate students, their research topics include LEDs in greenhouse lighting, LEDs in indoors lighting, Glare in the traffic, Office lighting, Signal lights in the peripheral vision, Vision at low light levels, New mesopic system, Development of mesopic photometry, Energy efficiency in buildings. There are students from China, Nepal, Romania and Portugal working in Lighting Laboratory.

Research
The research areas of Lighting Laboratory are divided into five groups: Indoor Lighting, Traffic Lighting and Vision, Light Sources and Energy, Lighting Measurements and Testing and Electrical Building Services. The research topics of Light Sources and Energy group have been lately: Characteristics of Lamps and Ballasts, Effect of Dimming and Cathode Heating on Lamp Life, Dimming According to Daylight, Energy Efficient Electric Lighting for Buildings, Usage and Control of LEDs in General Lighting, Usage of LEDs in Plant Cultivation.
**International Projects:**

- PROMILL Promoting Illuminating Engineering Studies, Research and Continuing Co-operation Between Europe and China (2003-2006)
- COST529 Efficient Lighting for the 21st Century
- IEA SHC Task 31 Daylighting Buildings in the 21st Century
- Whiteness Perception of Japanese and Finnish under Cool and Warm Fluorescent Lamps

**Lamp Life of T5 Fluorescent Lamps in Dimming Use**

The aim of the research was to find out the effect of dimming on lamp life of T5 fluorescent lamps. The other goal was to find out the optimal electrode temperature in dimming use. The electrode temperature determines the rate of loss of the electrode emissive coating. Thus, the electrode temperature directly affects the lamp life. The electrode temperature was measured with electrical measurements and with infrared camera. Measuring method based on the temperature dependence of the resistances of the metals was found to be accurate to some extent. If the electrodes were heated up evenly, the result was a good approximation. If the electrodes were heated up unevenly, the result was a too low temperature. The results show that the electrode temperature of T5 28 W lamps should be more than 700 °C. Results show that with proper electrode heating T5 lamps can be dimmed without decreasing their lamp life.
Notes, Scribbles, Doodles and/or Limericks