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TECHNICAL REPORT

ELECTRIC LIGHT SOURCES
STATE OF THE ART - 1991

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2. To develop basic standards and procedures of metrology in the fields of light and lighting.
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1. De constituer un centre d'étude international pour toute matière relevant de la science, de la technologie et de l'art de la lumière et de l'éclairage et pour l'échange entre pays d'informations dans ces domaines.
2. D'élaborer des normes et des méthodes de base pour la métrologie dans les domaines de la lumière et de l'éclairage.
3. De donner des directives pour l'application des principes et des méthodes d'élaboration de normes internationales et nationales dans les domaines de la lumière et de l'éclairage.
4. De préparer et publier des normes, rapports et autres textes, concernant toutes matières relatives à la science, la technologie et l'art dans les domaines de la lumière et de l'éclairage.
5. De maintenir une liaison et une collaboration technique avec les autres organisations internationales concernées par des sujets relatifs à la science, la technologie, la normalisation et l'art dans les domaines de la lumière et de l'éclairage.

Les travaux de la CIE sont effectués par 7 Divisions, ayant chacune environ une 20 de Comités Techniques. Les sujets d'études s'étendent des questions fondamentales, à tous les types d'applications de l'éclairage. Les normes et les rapports techniques élaborés par ces Divisions Internationales de la CIE sont reconnus dans le monde entier.

Tous les quatre ans, une Session plénière passe en revue le travail des Divisions et des Comités Techniques, en fait rapport et établit les projets de travaux pour l'avenir. La CIE est reconnue comme la plus haute autorité en ce qui concerne tous les aspects de la lumière et de l'éclairage. Elle occupe comme telle une position importante parmi les organisations internationales.

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Die Internationale Beleuchtungskommission (CIE) ist eine Organisation, die sich der internationalen Zusammenarbeit und dem Austausch von Informationen zwischen ihren Mitgliedsländern bezüglich der Kunst und Wissenschaft der Lichttechnik widmet. Die Mitgliedschaft besteht aus den Nationalen Komitees in 35 Ländern und einem geographischen Gebiet und aus 10 persönlichen Mitgliedern.

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Die Arbeit der CIE wird in 7 Divisionen, jede mit etwa 20 Technischen Komitees, geleistet. Diese Arbeit betrifft Gebiete mit grundlegendem Inhalt bis zu allen Arten der Lichtanwendung. Die Normen und Technischen Berichte, die von diesen international zusammengesetzten Divisionen ausgearbeitet werden, sind von der ganzen Welt anerkannt.

Tagungen werden alle vier Jahre abgehalten, in der die Arbeiten der Divisionen überprüft und berichtet und neue Pläne für die Zukunft ausgearbeitet werden. Die CIE wird als höchste Autorität für alle Aspekte des Lichtes und der Beleuchtung angesehen. Auf diese Weise unterhält sie eine bedeutende Stellung unter den internationalen Organisationen.

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This Technical Report has been prepared by CIE Technical Committee 7-07 of Division 7 'General aspects of lighting' and has been approved by the Board of Administration of the Commission Internationale de l'Eclairage for study and application. The document reports on current knowledge and experience within the specific field of light and lighting described, and is intended to be used by the CIE membership and other interested parties. It should be noted, however, that the status of this document is advisory and not mandatory. The latest CIE proceedings, publication or CIE NEWS should be consulted regarding possible subsequent amendments.

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FOREWORD

The following members of Technical Committee TC 7-07 'Light and Radiation Sources' took part in the preparation of this report. The committee comes under CIE Division 7 (General Aspects of Lighting).

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Electric Light Sources State of the Art - 1991

1 SUMMARY AND INTRODUCTION

In 1988 CIE publication No 77 "Electric Light Sources State of the Art - 1987" was published. This present report has been prepared by Technical Committee TC 7-07 and reflects the progress made in the period 1987-1991 in the field of light sources, radiation sources and their relevant electronic devices. Standardization is also included. The report, based on published literature, has deliberately been kept short and only new developments are included. For earlier work and more background information the reader is referred to CIE publication No 77. More detailed information can be found in the cited references, recently published overviews [1,2] and from data sheets, application information etc. supplied by manufacturers. In Table 1 an overview is given of the order of magnitude of main lamp parameters. Naturally this can only give a first impression. Detailed information must be obtained from the sources mentioned above.

Sources électriques de lumière - Etat de l'art 1991

RESUME ET INTRODUCTION

La publication no. 77 de la CIE relative aux "Sources électriques de lumière - Etat de l'art 1987" est parue en 1988. Ce présent rapport a été préparé par le Comité Technique CT 7-07 et reflète les progrès réalisés durant la période 1987-1991 dans le domaine des sources de lumière, des sources de rayonnement et de leurs dispositifs électroniques correspondants.

Les problèmes de standardisation y sont également inclus. Le rapport, basé sur la littérature publiée, a été volontairement court et seuls apparaissent les nouveaux développements.

Pour se documenter sur les premiers travaux et avoir une information de base, le lecteur se reportera à la publication no. 77 de la CIE. Une information plus détaillée pourra être trouvée dans les références bibliographiques citées, dans les travaux de synthèse récemment publiés(1,2), les feuilles de données et les applications etc. présentées par l'industrie. Des tableaux présentent une vue d'ensemble des ordres de grandeur des principaux paramètres des lampes. Ceci ne peut, évidemment, donner qu'une première impression. Des informations plus détaillées peuvent être obtenues à partir des sources d'information mentionnées précédemment.

Stand der Wissenschaft der elektrischen Lichtquellen - 1991

ZUSAMMENFASSUNG UND EINLEITUNG

Die CIE-Publikation Nr. 77 "Electric Light Sources - State of the Art 1987" wurde 1988 veröffentlicht. Der vorliegende Bericht ist vom Technischen Komitee TC 7-07 ausgearbeitet worden und beschreibt den Fortschritt im Zeitraum 1987-1991 auf dem Gebiet der Lichtquellen, der Strahlungsquellen und des wichtigen elektronischen Zubehörs. Die Normung ist ebenfalls berücksichtigt. Der Bericht, beruhend auf der veröffentlichten Literatur, wurde absichtlich kurz gehalten und enthält nur neue Entwicklungen. Für ältere Arbeiten und für tiefergehende Informationen wird der Leser auf die CIE-Publikation Nr. 77 verwiesen. Detailreichere Informationen können den zitierten Referenzen, neuerdings veröffentlichten Übersichten (1,2) und Datenblättern, Gebrauchsanweisungen usw. der Erzeuger entnommen werden. In der Übersichtstabelle (Tabelle 1) werden die Größenordnungen der wichtigsten Lampenparameter angegeben. Selbstverständlich kann dies nur einen ersten Eindruck vermitteln. Detaillierte Informationen sind den oben genannten Quellen zu entnehmen.

2 INCANDESCENT LIGHT SOURCES

2.1 General service incandescent lamps

Despite the fact that GLS lamps are more than 100 years old, new developments are still taking place. One example is a range of lamps with new outer shapes and coated on the inside with a light diffusing layer. This layer can be white or else in various pastel colours[3].

New reflector lamps have also been developed[4], an example being shown in figure 1. By using double reflection optics and a better matching of filament and optics, significantly intenser beams have been realized.

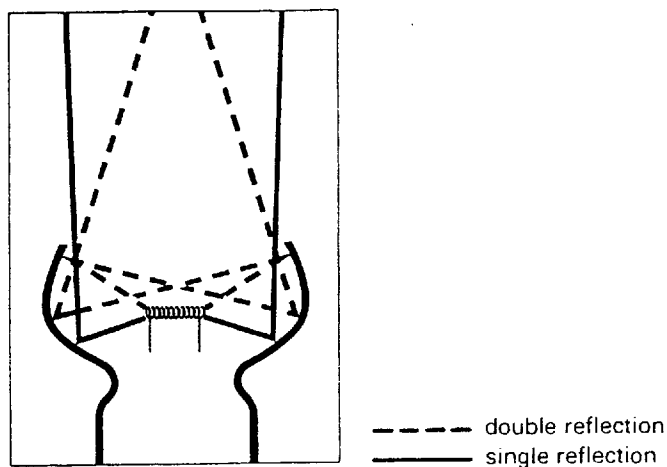
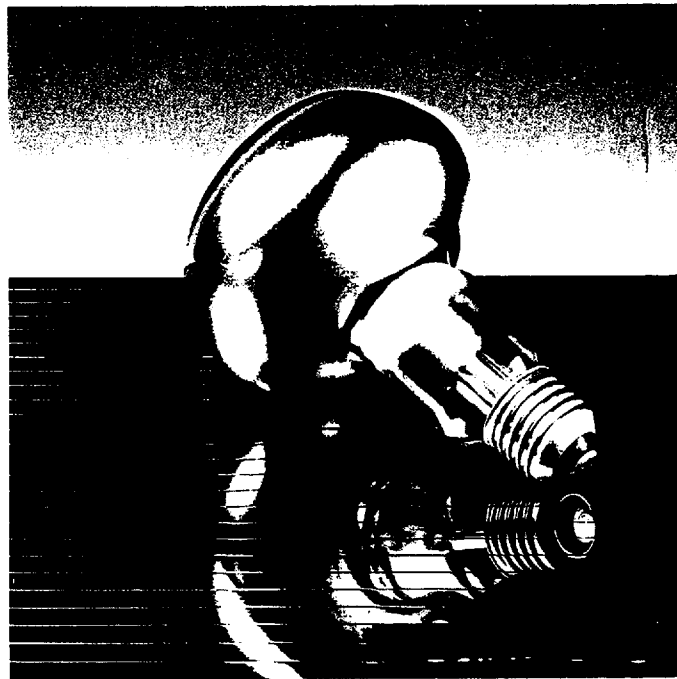


Figure 1. Incandescent reflector lamp with double reflection optics.

Table 1.
Order of magnitude of main lamp parameters

	Power (range in W)	Luminous Flux (range in lm)	Luminous Efficacy (range in lm/W)	Colour Temp. (range in K)	Colour rendering (range in Ra)	Lamp Life (range in h)
General Incandescent	10 - 1500	50 - 35000	5 - 25	2500 - 3000	100	100 - 2000
Tungsten Halogen	10 - 5000	150 - 120000	15 - 30	2800 - 3300	100	50 - 2000
Standard Fluorescent	4 - 200	150 - 15000	40 - 100	2500 - 6500	60 - 95	10000 - 20000
Compact Fluorescent	5 - 40	250 - 3500	50 - 80	2500 - 6500	80 - 90	5000 - 10000
High Pressure Mercury	50 - 1000	1500 - 60000	30 - 60	3000 - 6000	25 - 60	10000 - 20000
Blended HP Mercury	100 - 1250	1000 - 40000	10 - 30	3000 - 6000	40 - 50	5000 - 10000
Metal Halide	30 - 3500	1500 - 30000	50 - 125	3500 - 6500	50 - 85	2000 - 10000
High Pressure Sodium						
Normal	35 - 1000	2200 - 150000	70 - 150	2000	20	10000 - 25000
Colour improved and "White" versions	30 - 400	1500 - 40000	45 - 100	2100 - 2800	60-85	5000 - 15000
Low pressure sodium	15 - 200	1500 - 35000	100 - 200	1700	---	10000 - 15000

Notes on the table

- 1

This overview table is, by its very nature, incomplete. It can only give general trends and cannot be a substitute for data supplied by manufacturers. A detailed general overview can be found in publications such as the IES Lighting Handbook, (reference volume).
- 2

The power is the lamp power, except in those cases where the lamp and gear form one integrated unit.
- 3

The luminous flux is the initial value (usually at 100 hours).
- 4

The luminous efficacy is that of the lamp, except in those cases where the lamp and gear form one integrated unit. Gear losses depend on the type and quality of the selected equipment.
- 5

Lamp life: in general, for a given type of lamp, the shortest lives are for lamps with the highest luminous efficacy. One "universal" definition for lamp life does not exist. Depending on the lamp type and its application the life could be defined in various ways e.g. a given mortality percentage, a given percentage decrease in luminous flux, a given deviation from the specified chromaticity coordinates, etc.

2.2 Tungsten halogen incandescent lamps

During the last few years there has been a continuing diversification in low voltage halogen lamps, often integrated into one optical unit. High voltage halogen lamps at lower wattages have been introduced, for example in a PAR reflector with wattages from 75 W. The use of infrared reflecting coatings is increasing[5,6].

For car headlight applications in France a yellow tungsten halogen lamp has recently been introduced. By coating the lamp envelope with a multilayer interference coating the correct chromaticity coordinates are realized with a high luminous flux.

3 GAS DISCHARGE LIGHT SOURCES

Gas discharges form the basis of the light sources described in the following three sections. Recently two excellent overviews of this type of light source have been published[7,8].

4 LOW PRESSURE GAS DISCHARGE LIGHT SOURCES

4.1 Fluorescent lamps

Recent overviews of this type of lamp are to be found in references[9,10]. For the larger type of fluorescent lamp i.e. T-12 (38 mm diameter) there has been a reduction in diameter for some specific types e.g. a T-8 U-lamp[11] and a F40T10 lamp[12]. A main trend in the last four years has been more extensive study and operation of fluorescent lamps on high frequency electronic ballasts[13-15].

Another major theme is the further development of compact fluorescent lamps[16]. There are now a substantial number of sizes and wattages, a representative sample of which are shown in figure 2. Studies dealing with the ignition[17], interaction with gear[18,19] and the power balances[20] of such lamps have been carried out.

There has also been a further development in compact fluorescent lamps with integrated control gear. Not only has there been a diversification of lamps with conventional magnetic gear but various designs with integrated electronic gear have been introduced[21]. Figure 3 shows various versions of these lamps. Electrodeless compact fluorescent lamps have also been the subject of various investigations[22-24].

Another recent development is specially designed fluorescent lamp units for use in large outdoor colour display systems[25].

4.2 Low pressure sodium lamps

Of all the electric light sources available the low pressure sodium lamp has the highest luminous efficacy. Recently a new family of the lamps has been developed which have a still higher luminous efficacy (up to 200 lm/W) and a lower input power compared to existing lamps[26]. In order to further improve the lamp characteristics during life a new type of getter system has been developed for use in the outer bulb[27].

5. HIGH PRESSURE GAS DISCHARGE LIGHT SOURCES

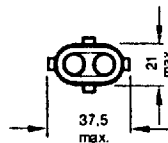
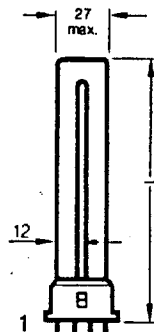
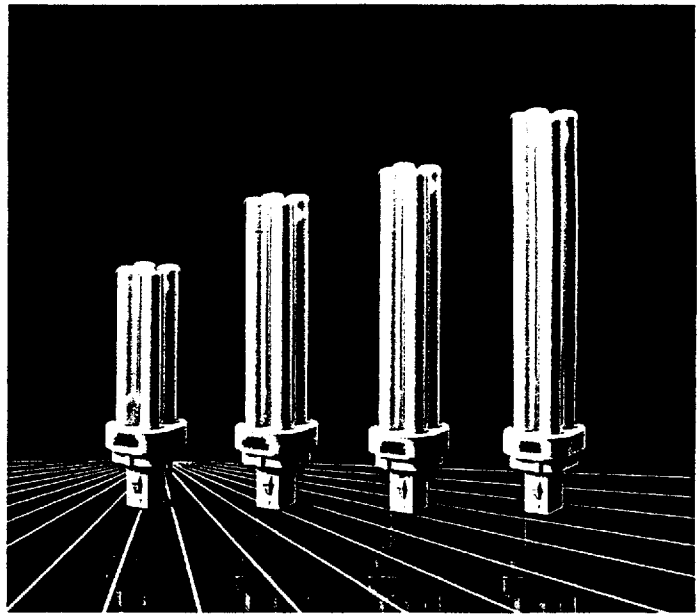
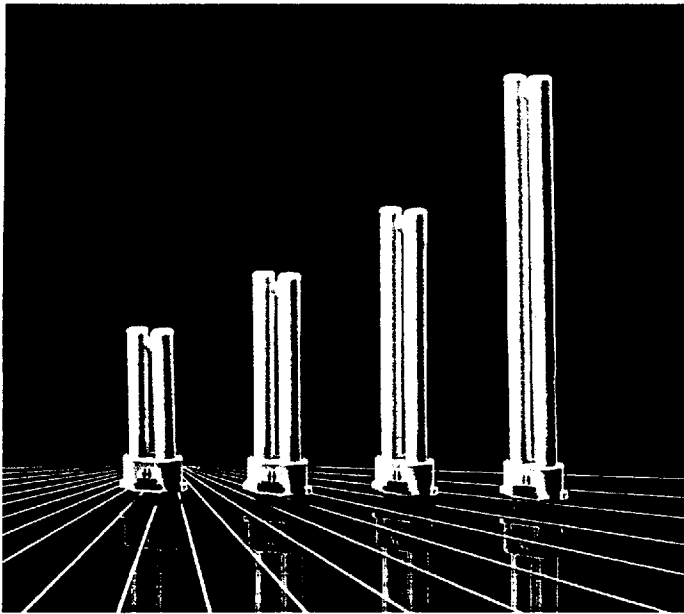
General topics valid for all high pressure lamps and which have been studied recently are acoustic resonances[28]. Such resonances can occur when these lamps are operated on HF electronic gear. Another topic for all high pressure lamps is internal starters which are located in the outer bulb or the lamp base[29].

5.1 High pressure mercury lamps

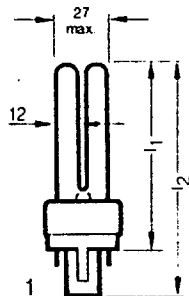
There have been no significant developments with this type of lamp.

5.2 Metal halide lamps

The development of low wattage metal halide lamps has continued[30-32] making such sources more suitable for applications such as display lighting[33]. Progress has also been made as far as the starting of metal halide lamps is concerned[34-37].



5 W		= 25 W	
7 W		= 40 W	
9 W		= 60 W	
11 W		= 75 W	



10 W		= 60 W	
13 W		= 75 W	
18 W		= 100 W	
26 W		= 2x75 W	

Figure 2. Representative sample of compact fluorescent lamps.



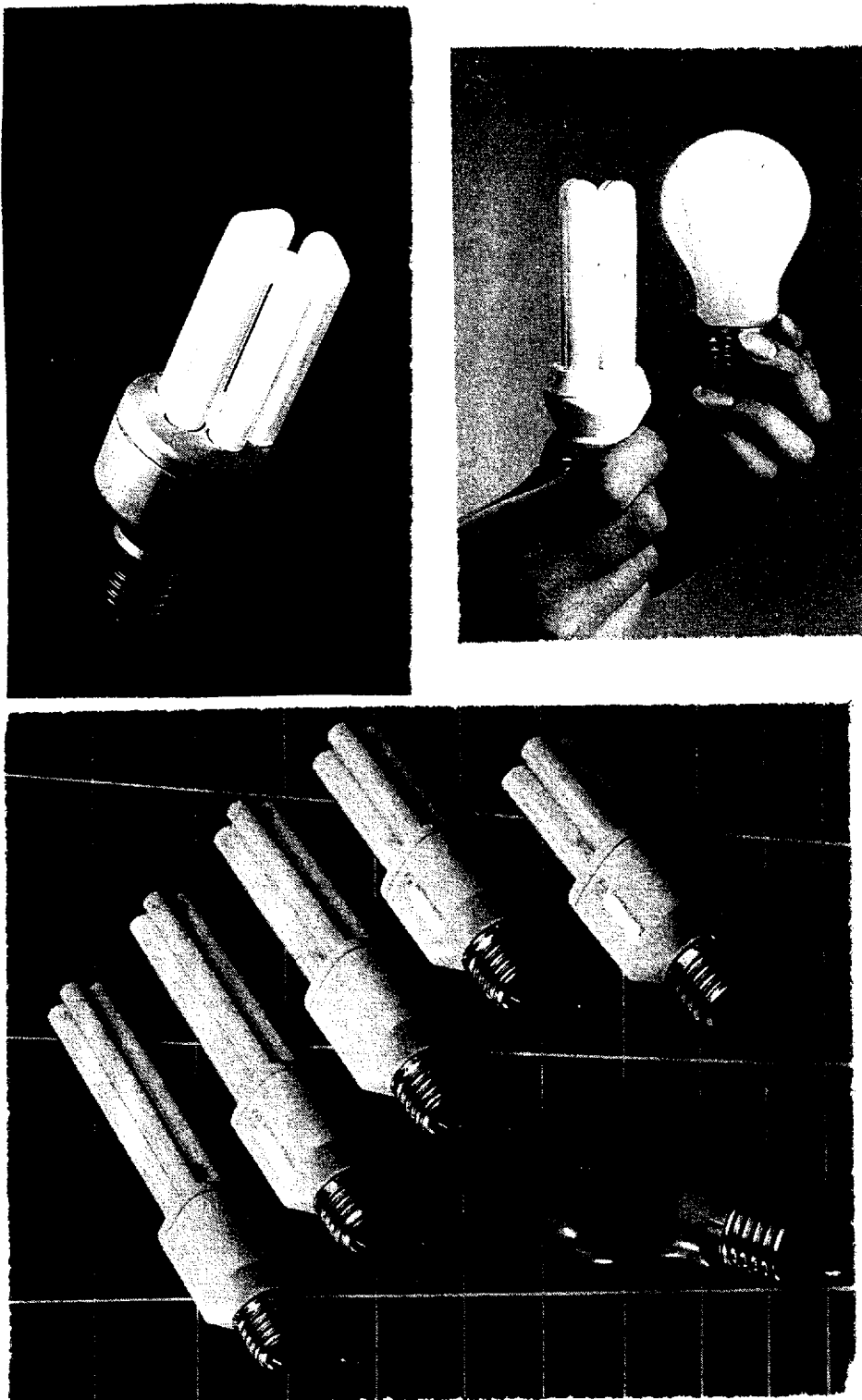


Figure 3. Various compact fluorescent lamps with integrated electronic gear

Perhaps the most far reaching miniaturization of metal halide lamps is for application in motorcar headlight systems. Such systems, based on miniature metal halide lamps, are being developed by various manufacturers[38,39].

New high wattage short arc metal halide lamps with a CCT of 5600 K have been developed for daylight spotlight applications[40]. For the lighting of sports stadia new lighting systems have been developed. They are based on high wattage metal halide lamps where special attention has been paid to the matching of lamp and optics[41,42].

5.3 High pressure sodium lamps

Recent overviews for high pressure sodium (HPS) lamps are to be found in references[43,44].

Lower wattage HPS lamps have been further developed[45]. Some work has been carried out to investigate the possibility of using very small HPS lamps in vehicle headlights[46]. A double arc tube lamp has been developed which is capable of instant restrike[47].

By increasing the sodium vapour pressure colour improved lamps with a CCT of 2150 K and a CRI of 60 can be realized. Such developments have been continued[48,49].

A further increase in the sodium vapour pressure results in lamps with a CCT ≥ 2500 K and a CRI ≥ 80 . These properties make such lamps most suitable for indoor lighting, display lighting and decorative outdoor lighting[50,51]. By pulsing HPS lamps it is also possible to increase the CCT[52]. This is also possible in lamps containing only sodium[53].

6. RADIATION SOURCES

6.1 Sources based on low pressure discharges

Rare gas discharge lamps have been developed which radiate in the red or near infrared. They are used in industrial applications such as two-colour facsimile, optical character readers, etc.[54].

6.2 Sources based on high pressure discharges

Further improvements have been achieved with ultraviolet sources for suntan and photoprint applications[55].

7. ELECTRONIC DEVICES

7.1 Starters

Various improvements to external electronic starters for High Intensity Discharge (HID) lamps have been realized in the past few years[56,57]. The basic principles of such devices are to be found in CIE publication No 77.

7.2 Electronic gear for fluorescent lamps

Recently there has been a rather rapid growth in the use of electronic ballasts for fluorescent lamps (see also section 4.1). A recent overview is to be found in reference[58]. Such systems often include dimming[59] and remote control features.

7.3 Electronic gear for HID lamps

The development of electronic gear for HID lamps has been much less rapid than was the case for fluorescent lamps. However it is now beginning to be used[60,61]. Hybrid systems consisting of a combination of a magnetic ballast and a electronic controller have also been introduced[62].

7.4 Control systems

As already noted in 7.2 with electronic gear it is relatively easy to add various control functions. An overview and evaluation of such control systems is to be found in reference[63].