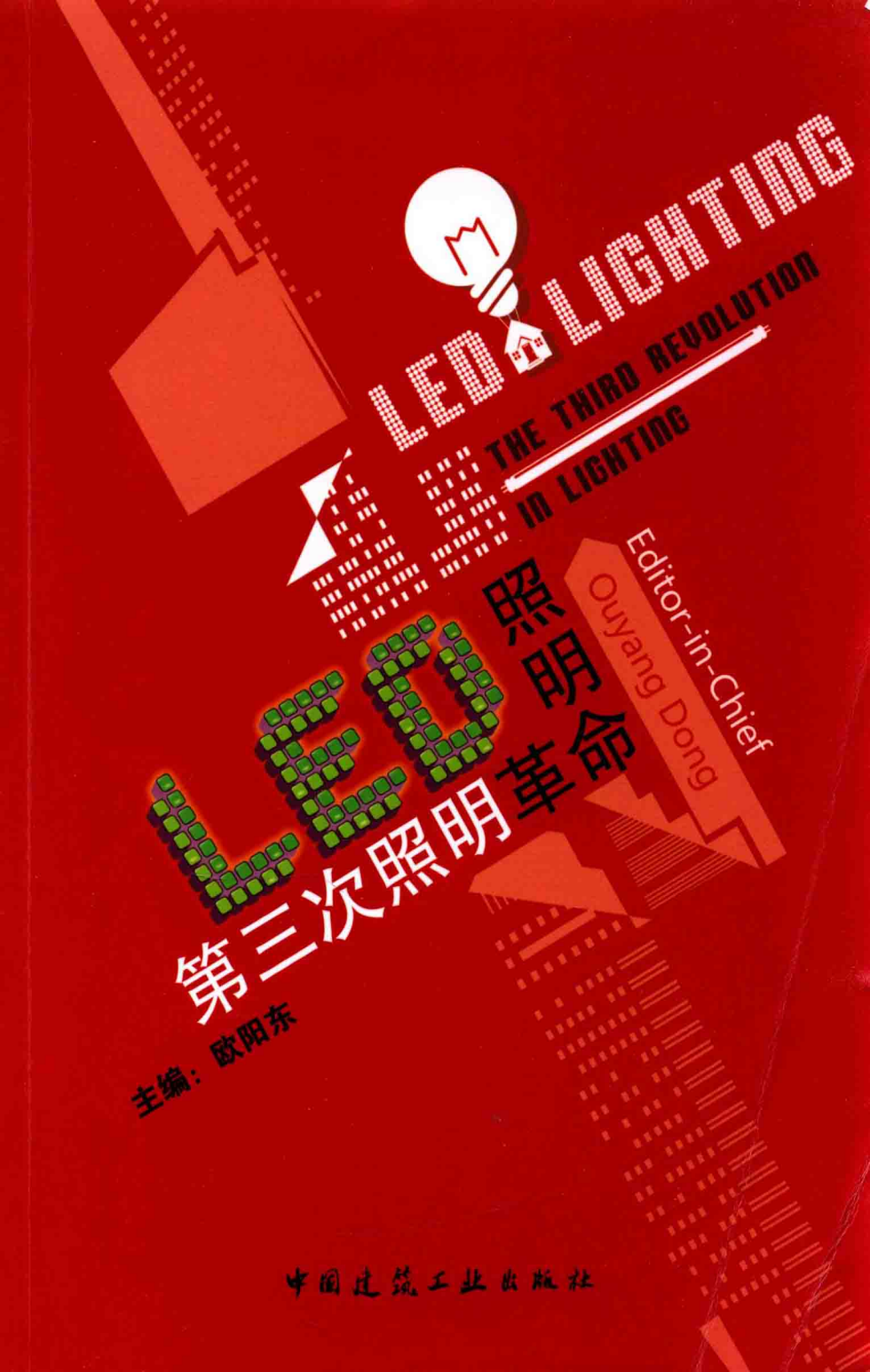
LED LIGHTING
THE THIRD REVOLUTION
IN LIGHTING
LED 照明
第三次照明革命
Editor-in-Chief
Ouyang Dong
主编：欧阳东
中国建筑工业出版社

LED Lighting
The Third Revolution in Lighting

LED照明
第三次照明革命

主编 **欧阳东**
Editor-in-Chief **Ouyang Dong**

中国建筑工业出版社
China Architecture & Building Press

图书在版编目（CIP）数据

LED照明——第三次照明革命 / 欧阳东主编. —北京：中国建筑工业出版社，2015.6
ISBN 978-7-112-17951-0

Ⅰ.①L… Ⅱ.①欧… Ⅲ.①发光二极管－照明设计 Ⅳ.①TN383.02

中国版本图书馆CIP数据核字（2015）第057545号

为贯彻执行国家技术经济和节能政策，推广宣传LED技术及相关LED照明产品，促进行业革命和进步而编写本书。全书共6章，内容包括：总则，LED照明技术，LED照明技术标准现状与发展规划，传统照明和LED照明的对比，LED照明技术的主要问题与对策，LED照明应用典型案例等。本书图文并茂、重点突出、中英文对照，有较强参考性、启发性、实用性。

本书既可供政府部门、建设单位、设计单位、施工单位、监理单位、照明厂商等单位的负责人、设计师、技术人员等学习参考，也可作为大中专学校相关专业师生及广大对LED照明感兴趣人士阅读。

责任编辑：刘 江 范业庶
装帧设计：北京美光设计制版有限公司
责任校对：张 颖 关 健

LED照明
——第三次照明革命
主编 欧阳东
*
中国建筑工业出版社出版、发行（北京西郊百万庄）
各地新华书店、建筑书店经销
北京美光设计制版有限公司制版
北京方嘉彩色印刷有限责任公司印刷
*
开本：880×1230毫米 1/32 印张：4 3/4 字数：173千字
2015年6月第一版 2015年6月第一次印刷
定价：49.00元

ISBN 978-7-112-17951-0
(27194)

编委会 Editorial Board

作者简介
About the Author

欧阳东

中国建筑设计研究院（集团）
院长助理、教授级高工
国务院政府特殊津贴专家
中国勘察设计协会建筑电气设计分会常务副理事长
中国建筑节能协会建筑电气节能专委会常务副主任
北京市和住房城乡建设部人才中心正高评委

Ouyang Dong

China Architecture Design & Research Group (CAG)
Assistant President, Professor-level Senior Engineer
Expert Entitled to Government Special Allowance (GSA)
Standing Vice President of China Intelligent Building Technology Information Association
Deputy Director of Building Electricity and Intelligent Efficiency Committee of China Association of Building Efficiency
Senior Judge of the Talent Center of the Beijing Municipality and the Ministry of Housing and Urban-Rural Development of the People's Republic of China.

欧阳东，1982年取得重庆建筑工程学院自动化专业的工学学士，2009年取得厦门大学EMBA高级经济管理硕士；2005年取得国家一级电气注册工程师。曾任综合所所长、机电院院长、运营中心主任等职务，现任集团院长助理、集团总法律顾问；社会兼职：《智能建筑电气技术》杂志社副社长；“中国智能建筑信息网”网站的理事长。

Mr. Ouyang Dong obtained his Bachelor's degree in Automation from Chongqing Institute of Architecture and Civil Engineering in 1982 and an Executive MBA (EMBA) in Senior Economics and Management from Xiamen University in 2009, and became a National First Class Registered Electrical Engineer in 2005. He was previously Director of the Comprehensive Department, President of the Electrical and Mechanical Institute, Director of the Operation Center of China Architecture Design & Research Group (CAG), and is currently Assistant to the CAG President and the Group General Counsel. His appointments include Deputy Director of the publication Intelligent Building Electrical Technology and President of the China Intelligent Building Information website.

作为工种负责人，参与了几十项大中型项目的设计工作，并取得了“北京梅地亚中心”等多个设计项目的国家级、省部级优秀设计奖。作为项目负责人，参与了多项企业级、部级和国家级科研项目，并取得了《建筑机电设备开放式通信协议研究》等多个科研项目的住房和城乡建设部华夏建设科学技术奖二、三等奖，主编了《医疗建筑电气设计规范》（中英文）；作为第一专利人，发明了《智能型灯光面板》等三项专利；作为主编或副主编完成了《建筑机电节能设计手册》等十几本著作的编著工作，并均已正式出版；独著《建筑机电节能设计探讨》、《设计企业管理研究》等十几篇技术论文和管理论文。主持过多次全国性行业会议，多次在行业会议上宣讲了《建筑机电节能设计研究》、《管理创新——企业发展之精髓》、《BIM技术——建筑设计的第二次革命》。

作为院（集团）院长助理兼设计运营中心主任，组织完善、调整、建立了一套《新的设计组织架构体系——项目经理和设计研究室主任的强矩阵管理架构》，取得非常好的经营业绩，各项经营指标连续四年均创历史新高。作为负责人组织BIM技术应用和推广工作，并取得了BIM最佳企业应用奖和五个BIM项目最佳设计奖。曾获得院（集团）管理创新特殊贡献奖、“十一五”科技创新奖、科研管理奖。

As principal of his profession, Mr. Ouyang has participated in designing dozens of large and medium-sized projects, and several of his design projects, such as Media Center Hotel Beijing have earned national and provincial excellent design awards. As project principal, he has been involved in several corporate, ministerial and national scientific research projects. Mr. Ouyang's multiple scientific research projects like Open Communication Protocol Study of Building Mechanical and Electrical Equipment were awarded second and third prizes in the China Construction Science and Technology Awards from the Ministry of Housing and Urban-Rural Development of the People's Republic of China and he also edited Code for the Electrical Design of Medical Buildings (Chinese and English versions). In addition, Mr. Ouyang holds three patents as the first inventor, including one for Intelligent Type lamplight Switch Panel. As chief or associate editor, he has completed the compilation of a dozen works that have been published, like Building Mechanical and Electrical Efficiency Design Manual, and a dozen of academic papers in technology and management, such as Discussion on Building Mechanical and Electrical Efficiency Design and Study on Design Enterprise Management. Moreover, he has chaired national industry conferences numerous times and presented papers on Study on Building Mechanical and Electrical Efficiency Design, Management Innovation: the Essence of Corporate Development, and BIM Technology: The Second Revolution in Architectural Design.

As Assistant President of CAG and Director of Design Operation Center, Mr. Ouyang has conducted, adjusted and established a set called New Design Organizational Structural System: Strong Matrix Management Structure of the Project Manager and Design & Research Office Director, and yielded outstanding business results with all business indicators hitting the record highs for four consecutive years. As principal, he has implemented the application and promotion of BIM technology, and was awarded the Best Enterprise with BIM Application and five Awards of the Best Design for BIM Projects. He was also awarded the CAG Special Services Award to Management Innovation, and 11th Five-Year Technology Innovation Award and Scientific Research Management Award.

序
Foreword

随着社会日新月异的发展，半导体照明在全球范围内都是朝阳的新兴产业。半导体照明具有节能减排、寿命长、体积小的特点，横跨了传统照明产业、电子行业等多个领域，具有广阔的发展前景，并符合“国家‘十二五’中长期科技发展规划战略研究”的发展方向。

在照明行业中，LED照明作为第三代照明新型光源已逐渐被采用，并替代原有的第一代或第二代照明光源。LED照明更是一个涉及多个领域、综合性很强的产业，它包含的大量信息，需要强有力的技术手段去采集、分类、分析、检索和传输；而建筑信息模型BIM（Building Information Modeling）技术作为数字建筑技术中出现的新概念、新理念和新技术，将为建筑设计革命提供强有力的技术支撑。2014年10月7日，日本科学家赤崎勇（Isamu Akasaki）、天野浩(Hiroshi Amano)和美籍日裔科学家中村修二(Shuji Nakamura)因发明了蓝色发光二极管以及基于此技术的白光LED照明应用，极大地促进了新一代高效节能的照明革命，并因此荣获了2014年诺贝尔物理学奖。

目前，国家通过政策扶持、资金扶持等多种手段，大力推广LED照明在照明领域的应用。中国为了更好地掌控LED产业，也有了自己的技术和产业发展思路：抓住照明产业革命的历史机

As the society develops rapidly, with the features of energy-saving, emission reduction, long life as well as small size, LED lighting is becoming a promising emerging industry at the global level. It spans the fields of traditional lighting industry and electronics industry with vast development prospects. Moreover, it accords with the development direction in the ‘the national 12th Five-year medium and long term science and technology development plan’.

In the lighting industry, LED lighting has been gradually used as the third generation new light source replacing the 1st and 2nd generations light sources. Being comprehensive across many areas, Led lighting includes plenty of information which requires powerful technical to gather, classify, analyze, search and transmit. At the same time, as the emerging new concept, new philosophy and new technique in the digital building technology, Building Information Modeling Technology is providing powerful technological support for architectural design revolution. On the 7th of October, 2014, Japanese scientists IsamuAkasaki and HiroshiAmano and Japanese-American scientist ShujiNakamura were awarded the Nobel Prize for physics for their invention of blue light emitting diodes and the white light LED lighting, which greatly promotes the new revolution of high-efficiency and energy-saving lighting.

At present, China is vigorously promoting the LED lighting application in the lighting field by means of policies support and Financial Support. In order to have a better development of LED industry, China has its own technology and industry development ideas. Seize the historical opportunity of the lighting industry revolution, and adhere to the government guide; Take enterprises as the subjects and marketization operation as the principle, and take technology innovation as the core and mechanism

遇，坚持政府引导；以企业为主体和市场化运作原则，以技术创新为核心、机制创新为保障；在解决市场继续的产业化技术的同时，加大对重大关键技术的研发投入，集中力量，重点突破，实现跨越式发展；通过全球范围内资源的整合、基地建设和龙头企业的培育，形成有自主知识产权和有国际竞争力的新兴产业。

在全球经济化、市场化、知识化、信息化的今天，也是跨行业、跨专业、跨产品的跨界社会，在这样一个挑战和机遇并存的环境下，中国的LED产业必将迎来一个崭新的未来。

innovation as the security; Increase investment into the major key technology research and development while solving the problem of industrialization technology. Concentrate and break through at key points and realize leap-forward development. Through the integration of global resources, base construction and the cultivation of leading enterprises, make LED lighting an emerging industry of Independent intellectual property rights and international competitiveness.

Under global economization, marketization, knowledge-driven and informatization and a cross-industry, cross-discipline and cross-product society presenting both opportunities and challenges, China LED industry is having a new future.

国家半导体照明工程研发及产业联盟执行主席

中国科学院半导体照明研发中心主任

Li Jinmin

China Solid State Lighting Alliance 2015.2.6 Executive Chairman

Research and Development Center for Semiconductor Lighting Chinese Academy of Sciences Director

Feb 6.2015

前言
Preface

形势 Trend	中国在“十一五”时期取得了辉煌业绩，国民生产总值（GDP）从26.6万亿元增加到51.9万亿元，年增速9.3%，跃升到世界第二位；5年科技累计投入8729亿元，年增速超过18%；在科技创新和节能环保的大背景下，LED 产业作为节能环保的重要产业之一；预计到2015年中国LED照明产业规模将达到5000亿元；因此，节能减排和低碳经济将是中国发展的永恒主题。 China obtained brilliant achievements during the 11th five-year plan in which China's GDP had an annual growth rate of 9.3%, an increase from 26.6 trillion Yuan to 51.9 trillion Yuan and the economy ranked second in the world. Investment in sciences and technology amounted to 872.9 billion Yuan in five years with an annual growth rate of more than 18%. Meanwhile, science and technology innovation and energy saving and environmental protection were proposed and LED industry should be an important industry of energy saving and environmental protection. The LED lighting industry scale was predicted to be 500 billion Yuan in 2015. Therefore, energy efficiency and emission reduction and low carbon economy are going to be the perpetual trend of development in China.
目的 Goal	在中国建筑行业，通过LED照明技术和国家补贴政策等方式，推广LED技术，促进行业科技进步。贯彻执行国家技术经济和节能政策，推广宣传LED照明产品，促进行业革命和进步，将LED产品大力推向市场，为国家的节能减排尽力。 In the construction industry in China, popularize LED technology and promote the industrial technical progress by way of LED lighting technology and national allowance policies. Implement national technical, economic and energy saving policies, generalize and publicize LED lighting products, accelerate industrial revolution and advancement as well as bring LED products onto market, so as to contribute to the energy saving and emission reduction of our state.

（续表）（Continued）

主题 Theme	2011年，科技部颁布《关于印发国家十二五科学和技术发展规划的通知》，节能环保位居七大战略性新兴产业之首，其中，LED照明又位居四大节能环保技术之首。国家将低碳经济作为带动经济增长的内生增长动力；半导体照明是中国在节能减排方面的成功突破口；光电子技术与微电子技术的融合，不仅带来光的革命，更带来高新技术革命。 In 2011, Ministry of Science and Technology issued 'the notice about printing and distributing the national 12th Five-year science and technology development plan', in which the industry of energy saving and environmental protection topped the seven strategic emerging industries, among which LED lighting topped the four technologies of energy saving and environmental protection technologies. The state regards the Low carbon economy as the endogenous growth force driving economic growth. Semiconductor lighting is the successful breakthrough of china in energy saving and emission reduction. The merging of optoelectronic and microelectronic technologies not only brings the revolution of light but also brings the revolution of high-tech.
需求 Needs	1.经济发展的需求（GDP、生产力、可持续健康发展等）； 2.技术进步的需求（手段、流程、质量、效率等）； 3.行业发展的需求（科技研发、节约投资等）； 4.社会进步的需求（节能环保、社会责任等）。 1.Economic development needs (GDP, productivity, sustainable and healthy development , etc.) 2.Technological progress needs (means, processes, quality, and efficiency, etc.) 3.Industrial development needs (science and technology R&D and investment savings, etc.) 4.Social progress needs (energy saving and environmental protection, and social responsibility, etc.)

（续表）（Continued）

内容 Content	总则，LED照明技术，LED照明技术标准现状与发展规划，传统照明和LED照明的对比，LED照明技术的主要问题与对策，LED节能改造案例等。 General, LED Lighting Technology, Current Situation & Development Planning of LED Lighting Technical Standards, Comparison between Traditional Lighting & LED Lighting, Main Problems & Countermeasures of LED Lighting Technology, LED-Based Energy-Saving Renovation Cases, etc.
对象 Object	政府部门、建设单位、设计单位、施工单位、监理单位、照明厂商等单位的技术人员等。 Technical personnel of governments, project owners, design units, construction units, supervision units and Lighting manufacturers.
特点 Features	图文并茂、突出重点、可借鉴性、中英文对照、参考性、启发性、实用性。 Rich images and texts, highlighting key points, adoptability, bilingual in Chinese and English, providing reference, enlightening and practicability.

（续表）（Continued）

不足 Inadequacies	由于大家都是利用业余时间，在短时间内的编制完成，采用了大量的国内外相关资料，翻译经验不足，若有不妥或不准确之处，请大家批评指正。 Inappropriateness and inaccuracy are inevitable due to the short compilation time as the editors wrote this book in spare time, the massive amounts of domestic and overseas relevant data used as well as the inadequate translation experience. Constructive feedbacks are welcome.

中国建筑设计研究院（集团）院长助理、
教授级高工、国务院政府特殊津贴专家
2015-2-6

Ouyang Dong
China Architecture Design & Research Institute (Group)
Assistant to the President, Professor-level Senior Engineer
Expert Entitled to Government Special Allowance (GSA)
Feb 6, 2015

本书重点摘要
Summary

1 总则
General

三次照明革命对照比较

Contrast of The Three Lighting Revolutions

时代 Age	第一次照明革命（1879年） The 1st Lighting Revolution (1879)	第二次照明革命（1938年） The 2nd Lighting Revolution (1938)	第三次照明革命（1962年） The 3rd Lighting Revolution (1962)
名称 Name	白炽灯 Incandescent Lamp	荧光灯 Fluorescent Lamp	LED
发明者 Inventor	1879年，美国科学家爱迪生（1847~1931）32岁发明了白炽灯。 In 1879, American inventor Thomas Edison（1847~1931）invented incandescent lamp when he was 32 years old.	1938年4月1日，美国通用电子公司伊曼（1895~1972）43岁发明了荧光灯（日光灯）。 On April 1, 1938, George Inman（1895~1972）of General Electric invented fluorescent lamp when he was 43 years old.	1962年，美国通用电气公司（GE）的Nick Holonyak Jr博士（1928~今）34岁发明了可见光的LED。 In 1962, Dr. Nick Holonyak Jr. of GE invented LED that gives out visible light when he was 34 years old. 2014年诺贝尔物理学奖联合授予日本科学家赤崎勇、天野浩以及美籍日裔科学家中村修二，表彰他们发明一种新型高效节能光源[蓝色发光二极管（LED）]。 In 2014, Nobel Prize in Physics was awarded to Isamu Akasaki, hiroshi Amano and Shuji Nakamura for their new invention of efficient blue Light-emitting diodes (LED).

（续表）（Continued）

时代 Age	第一次照明革命（1879年） The 1st Lighting Revolution (1879)	第二次照明革命（1938年） The 2nd Lighting Revolution (1938)	第三次照明革命（1962年） The 3rd Lighting Revolution (1962)
技术特点 Technical Features	用钨丝加热发光，属于热辐射光源。发光效率10~15lm/W。Giving light by heating tungsten filaments the lamp is a heat radiation light source. Luminous efficiency: 10~15lm/W.	用汞蒸气和荧光粉发光，属于气体放电光源。发光效率60~90lm/W。Giving light by utilizing mercury-vapor and fluoresence, fluorescent lamp is a gas discharge light. Luminous efficiency: 60~90 lm/W.	用半导体发光，属于固态光源。当前主流产品发光效率80~120lm/W，理论发光效率 可达350lm/W。LEDS use semiconductor to give light and belong to solid-state light. At present, the luminous efficiency of mainstream LEDS is 80~120lm/W. LED'S theoretic luminous efficiency can be 350lm/W.
优点 Strength	价格便宜，安装方便，技术成熟。Low price, easy to install, mature technology.	价格合理，节能较大，发光效率适中。Reasonable price, good energy-saving, medium luminous efficiency.	体积小、耗电低、寿命长、无毒环保，易于智能控制。Small size, low power consumption, long life, non-toxic and green, and smartly controlled.
缺点 Weakness	光效低，发热量大，寿命短。Low luminous efficiency, high heating value,short lifetime.	寿命一般。Medium lifetime.	散热技术；发光驱动电路。Heat dissipation technology and lighting drive circuit.

1.1 LED照明设计理念
Design Concepts of LED Lighting

功能需求：根据建筑功能，按照设计标准及规范，实现照明功能的要求。

Functional demand: Light up a building according to the building functions and the design standards and codes.

节能需求：在满足同等舒适度的条件下，实现照明节能。

Energy-Saving demand: Use less energy while light up a room and offer the same comfortability.

舒适需求：满足人的生理、心理要求，提高环境的光品质。

Comfortability demand: Fulfill people's physiological and psychological demands and light up the environment comfortably.

文化需求：营造光环境，提升建筑空间的艺术效果。

Cultural demand: Create better lighting to enhance the art effects of an architectural space.

1.2 LED照明产业应用
Applications of LED Lighting Industry

以LED为主线，产业上中下游覆盖诸多领域。

Concentrated on LED, the whole industry covers multiple fields.

LED通用照明市场渗透率在2015年将达到30%以上，白光发光二极管的发光效率达到国际同期先进水平，推动我国半导体照明产业进入世界前三强。

LED will have more than 30% of the shares in general lighting market in 2015. The luminous efficiency of white LEDS in China will be as advanced as that in the world. China's LED industry will rank top three in the world.

1.3 LED照明产业流程
Flow of LED Lighting Industry

1.4 LED照明基本要求
Basic Requirements of LED Lighting

视觉舒适： Visual Comfort:	光源的显色性、和谐亮度分布 Color Rendering of Photo Source and Harmonious Brightness Distribution
视觉质量： Visual Performance:	照度水平和眩光控制 Lighting Level and Glare Limitation
视觉气氛： Visual Ambience:	光源色温、光的方向和光的阴影 Lighting Color, Direction of Light and Modeling

1.5 LED照明产业现状
Current Situations of LED Lighting Industry

上游：LED芯片和封装材料企业，主要在珠三角、长三角、环渤海等地区；

Upstream: LED Chip enterprises and Packaging material Enterprises, most of which lie in Pearl River Delta, Yangtze River Delta and Bohai Rim.

下游：LED灯具企业，主要在珠三角、长三角地区。

Downstream: LED Lamp enterprises, most of which lie in Pearl River Delta and Yangtze River Delta Regions.

LED灯比白炽灯节电90%，LED灯比节能灯节电30%。

LED Light consume 90% less electricity than incandescent lamps do and 30% less electricity than energy saving lamps do.

为推动LED技术在我国建筑设计市场的应用发展，承担住房城乡建设部科研课题《中国建筑电气与智能化节能发展报告》，编写其中第六章。

In order to drive the application and development of led technology in China's architectural design market, we Undertake the Scientific Research Project of MOHURD Report on the Development of Electric and Intelligent Energy-saving in China Buildings and write Chapter 6 of it.

1.6 LED照明产业发展趋势
Development Trends of LED Lighting Industry

发展趋势之一：政策扶持
发展趋势之二：资金支持
发展趋势之三：技术发展
发展趋势之四：产品发展——替代传统照明
发展趋势之五：市场发展——LED照明市场前景

Trend 1: Policies Support
Trend 2: Financial Support
Trend 3: Technological Development
Trend 4: Product Development——Replacement of the Traditional Lighting
Trend 5: Market Development——Outlook of LED lighting market

1.7 未来LED照明创新技术
LED Lighting Innovation Technologies in Future

创新技术之一：解决飞机时差
创新技术之二：解决集中精力
创新技术之三：解决睡觉失眠
创新技术之四：解决果蔬保鲜
创新技术之五：促进植物生长
创新技术之六：解决交通站牌
创新技术之七：解决产品形态
创新技术之八：解决健康照明（舒适）
创新技术之九：解决智能控制（系统）
创新技术之十：解决可见光通信

Innovation Technology 1: Solve Jet Lag
Innovation Technology 2: Promote Concentration
Innovation Technology 3: Alleviate Insomnia
Innovation Technology 4: Fruits and vegetables Fresh-keeping
Innovation Technology 5: Promote Plants Growth
Innovation Technology 6: Transport Station Boards
Innovation Technology 7: Diversify Product Forms
Innovation Technology 8: Healthy Lighting (Comfort)
Innovation Technology 9: Intelligent Control (System)
Innovation Technology 10: Visible Light Communication