Session 2

Chair: Leonardo Gariboldi

Isabel Marília Peres (a) - Maria Estela Jardim,(b) - Fernanda Madalena Costa(a)
(a) CCMM, University of Lisbon, (b)Faculty of Sciences, University of Lisbon
Lisbon, Portugal
mariliaperes@ciberprof.com , mejardim@fc.ul.pt , facosta@fc.ul.pt.

The Role of the Artificial Lights in the Scientific Photography of the XIXth Century

1. Photometric Studies on Artificial Lights

Edward Charles Pickering considered that three great advances have been made in astronomy[1]: the invention of the telescope, commonly associated with the name of Galileo, the application of photography to the study of the stars and the photography of stellar spectra. The first photographic image of a star was obtained in 1850, by George P. Bond, with the assistance of Mr. J. A. Whipple, at the Harvard College Observatory. The first photograph showing the lines in a stellar spectrum was obtained by Dr. Henry Draper, of New York, in 1872. For these reasons in the second half of the 19th century there was a strong interplay in the development of astronomy research and two emerging branches of science, spectroscopy and scientific photography. Consequently studies on photometry and artificial lights were also done at the time.

At Harvard the work of Edward Charles Pickering and his brother William Pickering from the MIT (Massachusetts Institute of Technology) led to important innovations in spectrography enabling the publication of the prestigious Henri Draper Catalogue (fig. 1). The compilation of a photographic library of the stellar universe also began in 1885[2]. Early stellar spectra showed the distinctive absorption lines that astronomers used (and still use) to determine the stars' chemical composition and temperature. Astronomers used artificial lights and photometry to evaluate the spectra of “standard stars” with any stellar spectrum.

The properties of artificial lights were studied by scientists in connection with other works on the field of spectroscopy and astronomy. Robert Bunsen and Henry Roscoe in a paper published in 1857, “*Photo-chemical Researches*”[3], approached this subject. One problem associated with photochemical studies was the difficulty of colouring the flame with salt samples: different salts adhered to the platinum wire in different ways and the colour intensity and duration of flame were high variable. This was mentioned for the first time by Bunsen and Roscoe in 1856 with photochemical experiments. The scientists had been working with lumps of coal soaked in solutions of different salts before they were exposed to the flame. The light emitted from a Scott’s annular burner gave satisfactory results and was adequate for many photometric observations; however it was not sufficiently constant to be used for accurate measurements. The authors endeavored to find means to obtain a flame of coal-gas of constant dimension and luminous intensity.

---

[1] PICKERING, E.C. (1909). *The Future of Astronomy*. www.gutenberg.net

[2] The original HD Catalogue was published by Annie Jump Cannon (curator of astronomical photographs) and Edward C. Pickering (Harvard Observatory director) between 1918 and 1924.

[3] BUNSEN & ROSCOE (1857). Photo-chemical Researches, *Phil. Trans. Royal Society*, v. 147, p. 355-402.

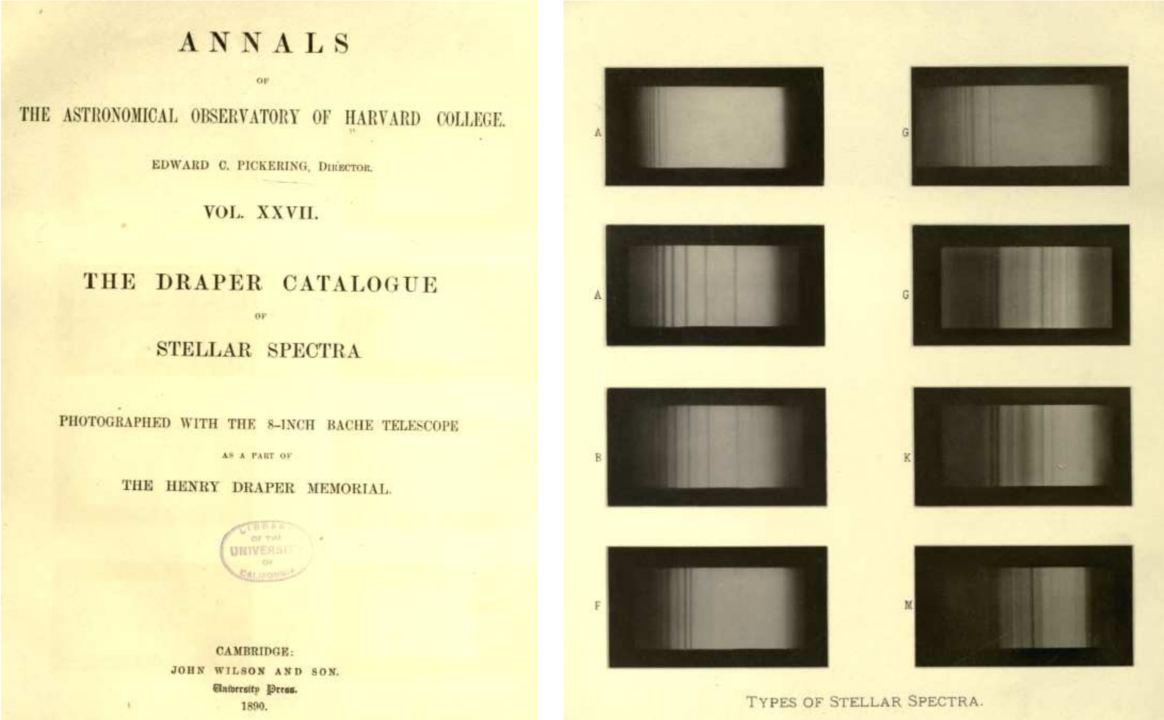

Fig. 1 - Cover and plate from the Draper Catalogue[4]

Later Bunsen adopted a different version of the platinum wire developed in Heidelberg by the British chemist Rowlandson Cartwell[5] and he adapted a burner, which Henry Roscoe brought from England, where the mixture gas-air could be controlled in order to produce different types of flames. In these studies they showed that the combustion of magnesium was a good and simple source of light for purposes of photo-chemical measurements. Magnesium's light had a great brightness and was very actinic.

In 1880 William Pickering[6] refereed the interest of photometry to determine the relative intensity of the component colours of the brighter lights: Candle, Sun, Gas Flame, Lime, Magnesium and Electric light. The standard adopted was the gas flame from an Argand burner. Pickering used a double-slit spectroscope with a grating, having the lines photographed in the glass. Looking through the instrument he could see the two superposed spectra. He traced spectra for different light sources based in their temperatures for the comparison with the sun's spectrum. He concluded that the spectrum of magnesium was the one more similar to the spectrum's sun.

Another important study was made by Frederick Rogers in 1891[7]. He made several determinations: temperature of the magnesium combustion, radiant efficiency, heat of the magnesium combustion and total efficiency of magnesium light[8].

[4] PICKERING, E. (Director) (1890). *Annals of Observatory of Harvard College – The Draper Catalogue of Stellar Spectra*, John Wildonand Son, Cambridge.

[5] HENNIG, J. (2001). Bunsen, Kirchhoff, Steinheil and the Elaboration of Analitical Spectroscopy. *The Making of the Spectroscope*. Munique, Leo S. Olschki Editores, p. 748.

[6] PICKERING; W. (1880). Photometric Researches, *Proceedings of American Academy of Arts and Scienc.*, V. XV, p. 236- 254.

[7] ROGERS (1891). Magnesium as a Source of Light, *Amer. J. Sci.*, vol. 43, p. 301.

From his experiments he could conclude: *"The spectrum of burning magnesium, as had already been pointed out by Pickering, approached much more nearly that of sunlight than does the spectrum of any other artificial illuminant."* and *"The total efficiency of magnesium light is about 10 per cent; as compared with 0,25 per cent, for illuminating gas."*[9]

In 1894 Keeler[10] called attention for the opposite behavior under varying conditions of the temperature of two lines in the spectrum of magnesium, and showed that these lines, taken together, "*give a means of estimating the approximate temperature of the absorptive atmospheres of the stars."*

In the same year, Edward Nichols and Mary Crehore in their "*Studies of the Lime Light*"[11] described an experiment to find out the changes observed in the Drummond light from the moment of ignition until the lime has reached its final state of incandescence. Measurements showed that the spectrum of limelight in its final state of incandescence gave readings which corresponded closely to those obtained by W. Pickering. They also pointed out that measurements[12] of the spectrum of the freshly ignited lime showed a degree of incandescence corresponding closely with that of the magnesium light, while the spectrum of the lime in its final condition showed a state of incandescence somewhat slightly inferior to that of the electric arc.

The second part of Nichols's investigation was made with the spectrophotometer in order to determine the law of incandescence, wave-length by wave-length, throughout the visible spectrum. The experiments he described showed that lime had the remarkable property, long since known to exist in the case of other oxides, of luminescence by heat. In other words, its radiation when freshly ignited was one corresponding to a temperature very much higher than that to which it was subjected. That was the case with magnesia, when the incandescent oxide was produced by the burning of magnesium ribbon, as had been shown by Rogers.

In 1900 Edward Nichols determined the "*Efficiency of the Acetylene Flame*"[13]. The measurements showed that acetylene flame, in a scale of radiant efficiencies, was very nearly equal to the arc light. Considering total efficiency he concluded: "*The magnesium flame alone had the very high radiant efficiency, superior to acetylene in this respect"*.

With these studies it was proved that limelight was stronger in the shorter wavelengths than arc light or any other artificial light, except magnesium light to which it showed a close resemblance, except in its final state of incandescence (fig. 2).

---

[8] By radiant efficient of a source of light Rogers meant the ratio of luminous energy to total radiant energy. For Rogers in order to determine the total efficiency of magnesium light it was necessary to know its heat of combustion. A new form of calorimeter was used to determine this quantity. Total efficiency was defined by Rogers as the ratio of luminous energy to the total energy expended in the production of the light. In order to determine this ratio it was necessary to know the ratio of radiant energy to total energy of combustion.

[9] ROGERS (1891). *Op. cit*., p. 310.

[10] KEELER, E. (1894). *The Magnesium Spectrum as an Index to the Temperature of the Stars* , John G. Wolbach Library, Harvard-Smithsonian Center for Astrophysics (Provided by NASA Astrophysics Data System).

[11] NICHOLS, E. L. and CREHORE, M. L. (1894). Studies of the limelight, *Phys. Rev*. (series 1), vol. 2, p. 161.

[12] "*The measurements consisted, as in all spectrophotometric work, in bringing the corresponding wave-lenghts of the two spectra to equal brightness*." *in* NICHOLS, E. L. and CREHORE, M. L. (1894). *Op. cit*., p. 167.

[13] NICHOLS, E. (1900). Efficiency of the Acetylene Flame, *Phys. Rev*. 21, p. 147.

TABLE I.

Radiant effi iency of various sources of light.

Source.	Observer.	Luminous radiation. / Total radiation.
Sperm candle.	Thomsen.	0.0210
Paraffine candle.	Rogers.	0.0153
Moderator lamp.	Thomsen.	0.026
Illuminating gas.	Thomsen.	0.0197
" "	Langley.	0.0240
" (bat's wing).	Rogers.	0.0128
" (argand).	Rogers.	0.0161
Incandescent lamp.	Blattner.	0.05 to 0.06
" "	Merritt.	Various values up to 0.06
" "	(From integration of Abney and Festings' curves).	0.055
Welsbach mantle.	Stebbins.	0.02 to 0.07
Lime light (new).	Crehore.	0.14
" (old).	"	0.084
ACETYLENE.	Stewart and Hoxie.	**0.105**
Arc light (Foucault).	Tyndall.	0.104
"	Nakano.	0.104
"	Marks.	0.08 to 0.13
Magnesium light.	Rogers.	0.125
Geissler tubes.	Staub.	0.32

Fig. 2 – Nichols' table: Radiant efficiency of various sources[14]

3. Photography and Artificial Lights

The photographic emulsions used in the 19th century interacted mainly with blue-violet end of spectrum. Artificial lights have been tested in photography since the Daguerrian process. However research on artificial lights was greatly developed after the discovery of the wet-collodion photographic process.

The most important required features of artificial lights for photography were: actinism in the blue-violet end of spectrum, intensity of the light and efficiency in illumination.

The most important types of artificial lights used in photography were:

Limelight or calcium light was discovered in 1824 and improved by Thomas Drummond. This weak light was produced by heating calcium carbonate. The intense heat required for the reaction was supplied by burning hydrogen gas into oxygen. The hot flame was impinged on a cylinder of calcium carbonate. The first to use it for photography was a French photographer Antoine Claudet in 1841.

[14] NICHOLS, E. (1900). *Op. cit.*, p. 221.

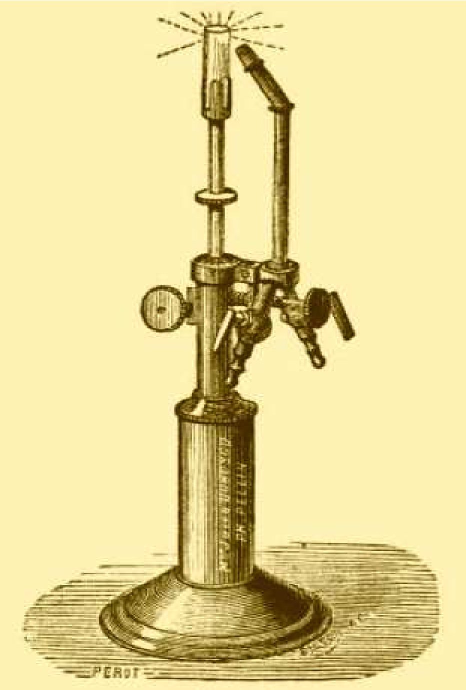

Fig. 3 – Duboscq's limelight[15]

After 1850, coal gas was used as an alternative to limelight. Coal gas was in full use for lighting big places as well as photographic studios but coal gas burners were inconvenient and unsafe, causing fires.

Arc light was produced as an electric current passes through two carbon rods held at a fixed distance. Although electric lights were first suggested to be used in 1851, it was the famous photographer Nadar who employed them in 1859 for portraits and later in 1861 in the catacombs of Paris where he took some remarkable photographs despite the fact that it was quite difficult to do it in the underground.[13]

Chemical lights have been used for daguerrian portraits since 1856.There were some lamps designed to use with chemical lights namely for carbon disulphide and nitrogen dioxide by Sell in 1874. They were good actinic lights but produced dangerous fumes which prevented the use of these lamps.

Bengal light was a mixture of potassium nitrate, sulphur and antimony sulphide. In 1812 a physicist Seebeck had observed that Bengal light emitted a bright light.

Following the work by Bunsen and Roscoe on the photochemical properties of magnesium, Sonstadt began experimental operation of full-scale industrial techniques of producing magnesium; with his patent and soon afterwards the Magnesium Metal Company, a Manchester industrial firm, was founded for this purpose. Alfred Brothers, an English photographer, was one of the first in 1864 to use magnesium in portraiture.

At first magnesium was as expensive as most of the illuminants already mentioned. However it was easier to use, suitable for wet plate collodion and very actinic for the blue-violet end of spectrum.[16]

[15] MAISON JULES DUBOSCQ (1885). *Historique & Catalogue de tous les Instruments d' Optique Supérieure Appliqués aux Sciences et a l'Industrie,*p. 5.

[16] EDER, J. M. ((1890*). La Photographie a la Lumière du Magnésium,* Gauthiers-Villars, Paris.

Many lamps were designed for this illuminant. The first lamps were constructed to use magnesium in the form of wire (Bunsen lamp, fig. 4) and ribbon (Solomon and Grant lamp, fig. 5).

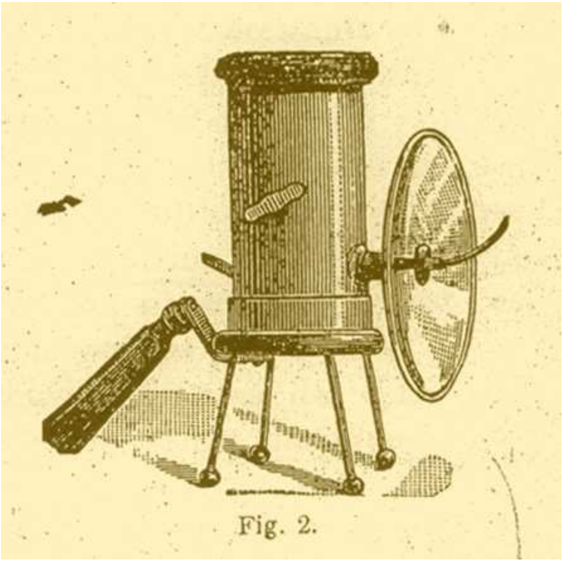

Fig. 4 – Bunsen lamp wire burner (1860)[17]

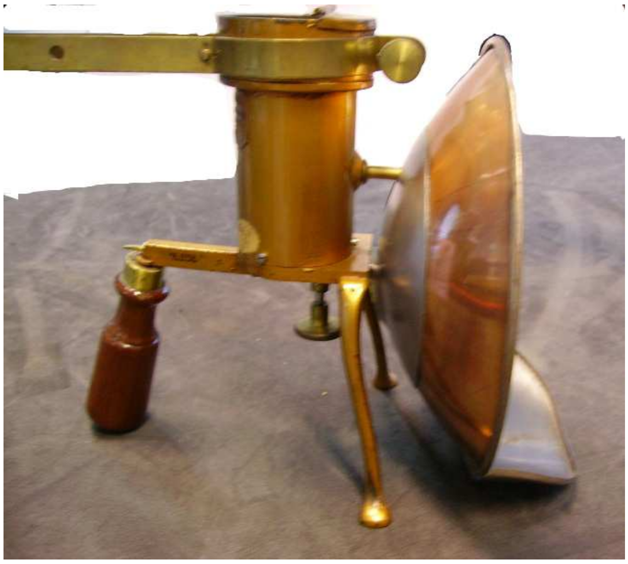

Fig. 5 – Solomon Lamp with ribbon burner - CNAM[18]

As experiments proved that magnesium in powder form was more efficient as an illuminant, lamps for powder were designed. The principle common to all of them was the projection of magnesium powder in a very hot flame. Other lamps that employed magnesium as a powder or in the form of an explosive mixture (flashpowder) were: the photosphere - Conti (1885); the photogenic revolver – Ranque (1890) and the flashpowder lamp - Paul Nadar lamp (1891)[19].

3. Scientific Applications of Artificial Lights

The first use of artificial lights was in portraiture in the studio but also in underground photography which allowed the general public to see how caves and mines looked like. Many photographers started a good business of selling underground photographs (mostly as stereophotographs). Later on, a systematic scientific study of caves began using underground photography. The exploration of caves made possible a better knowledge of the geology and the physics of the earth and so a new branch of science was born, speleology. Besides caves, other cavities where the light of the sun did not penetrate, could be explored and studied like mine and subterranean tunnels.

The first scientists to do a scientific survey of the underground using photography were the French explorers Martel and Vallot who studied many caves in France as in other countries. They advocated the use of magnesium light as a powder, not in the form of flashpowder which could easily initiate a quite dramatic explosion in a cave or a mine. Martel, in his book[20] recommends the use of the Nadar lamp as it has a small volume and weight and could give a flash light continuously or intermittently.

[17] LONDE, A.(1912). *La Photographie à la Lumière Artificielle*, Octave Doin, Paris, p. 21.

[18] CNAM - Inv. : 16938-0000 (M.E. Jardim, 2008)

[19] FOURTIER, M. H. (1895). *Les Lumières Artificielles en Photographie*, Gauthiers-Villars, Paris.

[20] MARTEL, E.-A. (1903). *La Photographie Souterraine*, Gauthiers-Villars, Paris.

In Portugal magnesium light was first used in cave exploration by Jose Julio Rodrigues a scientist and professor of Chemistry at the Polytechnic School of Lisbon[21]. He photographed a cave, Furna do Pico da Cruz, in the island of Terceira, Azores. From the account of the experiment he wrote in the periodical Occidente in 1892[22], we concluded that he used magnesium as an illuminant in the form of powder without a lamp. Two photomechanical prints of these photographs were published in the Occidente (fig. 6)

Fig. 6 – Furna do Pico da Cruz's photogravures (Occidente, 1892)

In the late 19th century Louis Boutan[23] began to photograph the underwater world for scientific purposes using a magnesium lamp. The design shown in figure 7 is similar to a previous one of a Chauffour system: A barrel full with air kept the alcohol lamp alight. Into this flame magnesium powder was injected.

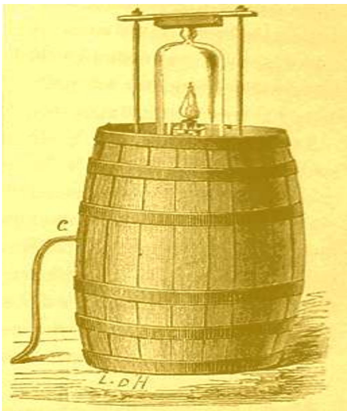

Fig. 7 – "*Lampe photo-sous-marine au magnésium*" (Boutan, 1900)

[21] Rodrigues was also a pioneer in the development of photomechanical processes applied to cartography. Further information see: JARDIM, M.E., COSTA, F.M. e PERES, I. M. (2008). José Júlio Rodrigues e a sua Contribuição para o Desenvolvimento da Cartografia Portuguesa e dos Processos Fotomecânicos do Século XIX, *in Actas do II Simpósio Luso-Brasileiro de Cartografia Histórica*, Lisboa

[22] OCCIDENTE (1892). p. 182-184.

[23] BOUTAN, L. (1900). *La Photographie Sous- Marine et les Progrès de la Photographie*, Schleicher Frères, Paris.

Albert Londe was an influential French photographer, medical researcher and chronophotographer. He is remembered for his work as a medical photographer at the Salpêtrière Hospital in Paris, funded by the Parisian authorities, as well as being a pioneer in X-ray photography. During his two decades at the Salpêtrière he took many medical photographs of mental patients using magnesium as an illuminant and a Fribourg and Hesse lamp[24].

4. Artificial Lights: Teaching and Popularization of Science

Artificial light also played an important role in the experimental teaching and popularization of science as they were used in projection lanterns. At Harvard, for instances, Pickering's plan of the Physical laboratory included the projection of spectra for the student's experiments with limelight as an illuminant.

Those projection lanterns were commercialised by the maker Duboscq; they were available for sale in the Duboscq's catalogue of 1870[25], in the section on spectroscopy. The maker referred classic experiences of spectroscopy, namely the sodium line D experience; he suggested the settings which we can see in figure 8. In the book written by one important Chemistry professor at Polytechnic School and Sciences Faculty of Lisbon, Achilles Machado, a complete description of the experience is found[26]. He reported the use of the voltaic arc to obtain continuous and discontinuous spectra.

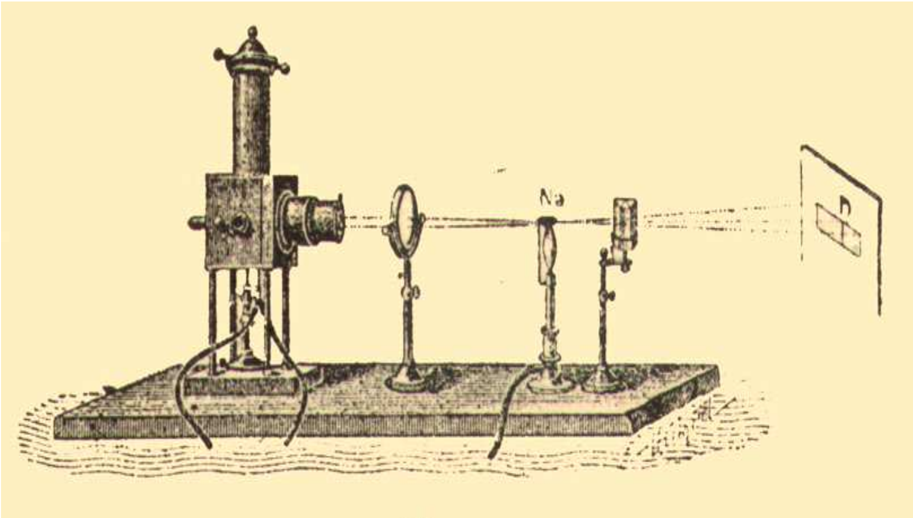

Fig. 8 – The sodium line D experience

At this time chemistry and physics professors used a similar methodology to teach spectroscopy. It was considered that this type of demonstration activity was only complete if the students had the opportunity to compare spectra acquired by them thorough experiments with spectra already available in catalogues. Duboscq, in 1870, offered for sale tables of spectra to Physics cabinets as well as to Chemistry laboratories. Those tables contained spectra of alkaline metals and alkaline-earth metals as well as spectra of nebulas. They were

[24] LONDE, A. (1893). *La Photographie Médicale: Application aux Sciences Médicales et Physiologiques*. Paris, Gautier-Villars.

[25] J. DUBOSCQ (1870*). Catalogue Raisonné des Spectroscopes*. Paris, J. Duboscq, Opticien.

[26] MACHADO, A. (1917). *Análise Química Qualitativa - Lições do Professor Achilles Machado*. Lisboa, Faculdade Ciências

built under the supervision of Bunsen and Kirchhoff[27]. According to Hentschel[28], Bunsen and Kirchhoff's colour maps, which were found in most laboratories, were of great importance to the students's training for the observation and identification of spectral lines and served as useful guides for the students' representation of observed spectra.

A particular example of an artificial light that had multiple uses was limelight. At first limelight was used in a projection microscope, then as a powerful signal light which could be seen for many miles, and eventually it was adapted for use in the magic lantern (fig. 9).

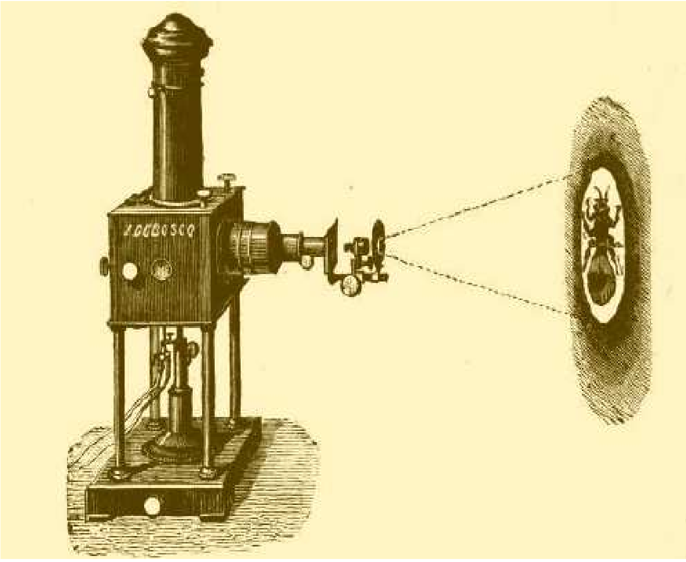

Fig. 9 – Projection microscope with limelight[29]

We can conclude that by the end of the 19th century, research on artificial lighting techniques was fundamental in the development of scientific photography, mainly in the field of physics, geology, oceanography, medicine and astronomy. The use of these illuminants was also very important for the teaching and popularization of science in public and private institutions.

Acknowledgements

The authors wish to express their gratitude to: Institut Océanographique de Paris, Musée des Arts et Métiers (CNAM), Museu de Ciência da Universidade de Lisboa and Société Française de Photographie.

[27] DUBOSCQ, J. (1870). *Op. cit.*, p. 14.

[28] HENTSCHEL, K. (1999). The Culture of Visual Representations in Spectroscopic Education and Laboratory Instruction, *Physics in Perspective*, Birkhäuser Verlag, Basel, p. 307.

[29] MAISON JULES DUBOSCQ (1885). *Op. cit.*, p. 15.