Material Culture in the History of Physics: The case of a He-Ne Laser

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Material culture approach is a useful tool for historians of science. This essay is based on the analysis of a He-Ne laser produced between 1960s-1970s by Spectra-Physics, in Deutsches Museum collections. I will focus on the history of lasers and discuss the different ways to an artefact study, highlighting the importance of this instrument for the History of Science and museums. I argue that this laser with a largely unknown history has several characteristics shared with Recent Scientific Heritage, which is a challenge for documenting and preservation.

Keywords: Material culture, Recent Scientific Heritage, laser

Introduction

The present essay is the output of the international seminar on Material Culture in the History of Physics, which took place at the Deutsches Museum in Munich, from February 26th to March 2nd, 2018.

The workshop gave new approaches to the history of science narratives through the use of objects as primary sources. There, we discussed different models to analyse unknown objects. The approach provided by the Winterthur model is based on five artefact properties, equivalent to the significant facts about an object (history, material, construction, design and function) and four operations (identification, evaluation, cultural analysis and interpretation) (Fleming 1974,1982). This model was developed in the context of decorative arts at the Winterthur Museum. The Winterthur model does not cover tacit knowledge or the practical function/use of an artefact (and its significance) could be a big challenge to answer without understanding the function and the working principle.

Several models have been proposed meanwhile. Pearce criticized several properties defined by Fleming (Pearce 1994) and proposed a model – or method – aiming at a broader approach to archaeological artefact study. Comparing both models, we can argue that the two dimensions of Fleming model are more easily adapted to the material culture study of scientific instruments than Pierce's model, which only addresses one dimension. It’s important to say that these models are a starting point for the research.

To surpass some of Fleming’s constraints, recent approaches aim at understanding the function of an instrument or giving new insights to the material and immaterial development of certain scientific instruments. The replication method (Heering 2010) is a powerful tool to document manufacturing technics and scientific development when re-enacting historical devices or building similar ones (Heering 2008).

In this essay, I will use an approach to artefact study proposed by Gessner (Lourenço & Gessner 2014). Gessner’s model, based on Winterthur and specifically developed to the study of scientific instruments, combines multiple sources (material, documental, literature, oral) and is organised into two dimensions: time and similarity. The dimension of time introduces a distinction between the present and the historical past of the scientific instrument under analysis, while similarity distinguishes between the individual artefact (e.g. a particular thermometer) and its shared proprieties with its broader class/category (e.g. all thermometers).

The combination of these two dimensions results in a table of four quadrants I, II, III and IV that can be used as a tool for scientific instruments’ analysis. From the point of view of the history of science, Gessner’s model has advantages in comparison with Fleming’s, namely the more clear introduction of historical dimension (e.g. quadrant IV is the biography of the instrument under study) and the material comparison with similar instruments that exist today in museum collections (e.g. quadrant II). As a result, more research questions adequate to the study of scientific instruments are raised, making this model a particularly interesting approach to object-based studies in the history of science.

	Singular Aspects	Generic Aspects
Syncronic view	• What are the measures? • What is the shape? • Does the object have inscriptions? (Brand, logotype, serial number, place of manufacture • What are the constituent materials? • It's necessary to use different objects to proper functioning? • There are missing parts? • What is the state of conservation? Requires restoration?	• What is the working principle? • This object belongs to which class? • What is the generic designation? • What is the way of use? • It is necessary any support to sustain the laser?
Diachronic view	• What is the place and date of making? • What is the provenence? • How long this object was in use? • In which context this object was accessioned? • There is any relation between this object and Munich Universities? • It is possible to identify a downgrade from University to museum workshops? • The object was used for demonstrations? • What is the origin? Who purchased? • In which (critical) moment the object was put aside?	• What is the context of use? • It was used in teaching contexts? • What kind of experimental procedures were performed with this device? • What is the importance for experimental activity/ research • How these objects evolved throughout time? • This object is still in use? • Which kind of knowledge is necessary to operate the device? • This type of objects was present at physics laboratories in the 20th century? Or they are unusual? • Who developed this instrument? In which context was developed? • What is the context of production? Manufacture or industrial production?

Fig. 1 The He-Ne laser: research questions organized according the four quadrants of Gessner’s model

In the specific case of the He-Ne laser from the Deutsches Museum collection (catalogue No. DMM 2016 - 3T1/ DMM 2016 - 3T2), the research questions are raised (see Fig. 1), which I will develop in the following sections. Other sources used were: trade catalogues, museum databases, online laser sellers, oral history/interviews and secondary literature.

Approaching the Instrument (QI & QII)

This type of instrument is designated a ‘He-Ne laser’. It is part of the Deutsches Museum collection, where c. 30 other artefacts related to laser history (J. Hagmann 2018, pers. comm., June 29) can also be found, such as an early commercial Elliott HeNe laser[1], prototypes and ellipsoid resonators by Siemens. Since 2015, the Deutsches Museum also has fragments of Theodore Maiman’s laser, the first Ruby laser to be built in 1960 (Deutsches Museum 2015).

The approach to the instrument was based on visual examination and tactile manipulation of the instrument. However, according to the objectives and resources available, this approach could include experimental methods such as microscopy and x-ray-fluorescence. Re-enacting experiments through replication method is also a possibility, depending on the object type, its conservation state and the experimenter skills.

The instrument encompasses two separate parts (see Fig. 2). The first is a parallelepiped plastic box with grey colour. It appears to have been used, with some scratches, dust and old label traces.

Fig. 2 He-Ne Laser and power supply/exciter. Source: Deutsches Museum Munich © Miguel Teixeira.

On the cover, it is possible to identify one black female socket with three round connectors with a thread to fix the male plug. This socket has 3 colour marks (blue, green and white). A few centimetres to the left it’s possible to identify a rubber

[1] The founder of this company was sales manager for Spectra-Physics UK. For further information please see: https://www.elliotscientific.com/About-Elliot-Scientific (Accessed May 1, 2018).

protection to the exit of a grey cable with a male plug for electricity (European type). It has 12 cross-head screws doing the link between the box base and its cover. The length of the box is 18,59cm, the wide is 9,53 cm and the high is 7 cm. On the top of the box (cover) we can identify two labels. One orange with the inscription "230 VOLTS" and another label – silver – with the inscription printed and engraved: "Spectra Physics / MODEL NUMBER 236/ SERIAL NUMBER 3519 959 / MADE IN U.S.A". On the base of the box there is another label, white, with the inscription: "DMM 2016 - 3T2", equivalent to the catalogue number attributed by Deutsches Museum.

The second part of the instrument has a cylindrical shape, metallic with a grey colour and two metal strips at both ends. Some parts are scratched, especially on the front of the tube – scratches and a sign of a black marker. In the front of the tube it is possible to identify an outer ring of black coloured metal with the inscription "SPECTRA PHYSICS / MODEL 136 LASER". There is also a small hole with a glass cover. Over the whole front there is a track for a slide – a plastic and rubber piece with an oval opening, with evidence of a missing piece. On one end of the tube is the inscription "DMM 2016 - 3T1" (black marker) and a grey cable with a black male plug with three connectors (see Fig. 3). This plug also presents the same colour marks described for the object "A". In the centre of the cylinder is a silver label printed and engraved with the inscription: "Spectra Physics / MODEL NUMBER 136/ SERIAL NUMBER 3651 803 / MADE IN U.S.A".

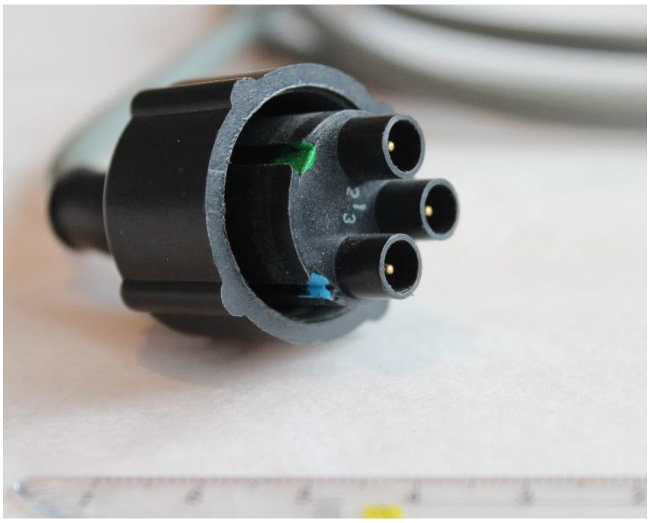

Fig. 3 Laser male plug with three connectors. Source: Deutsches Museum Munich © Miguel Teixeira.

Several dozens of similar instruments were found in European and American museums' databases, such as the Science Museum (London), the National Museums of Scotland (Edinburgh), the Musée des arts et métiers (Paris), the Collection of Historical Scientific Instruments (Harvard) and the National Museum of American History (Washington). Although the same model could not be found in any museum database, several types of laser were identified, from He-Ne laser discharge apparatus prototype to the applications in supermarket scanners and laser levels, both developed by Spectra Physics company. Some have their power sources[2].

The earliest laser object identified, soon after the first laser experiments in the late 1950s, is a discharge apparatus from 1960[3]. The Collection of Historical Scientific Instruments at Harvard University has an ‘early laser’, c.1963[4] developed by the Nobel Prize Nicolaas Bloembergen (1920-2017). From the first laser years, the Science Museum has a Spectra-Physics 125 – He-Ne gas laser and an exciter power supply (Spectra-Physics 250) - with a serial number similar to the laser in study. It was used in the British Aerospace laboratory in Bristol for optical tracking and other experiments in the field of weapons technology[5].

The majority of the lasers in museum collections are prototypes or part of important experiments in laser history. Some were manufactured in laboratories, by scientists, technicians while others – fewer – result from mass production by companies such as Spectra-Physics, Scientifica Cook and C W Radiation Inc., among others. This raises an interesting question about what gets to be preserved in museums – not so much the use but the initial development.

The front of the laser tube appears to be different from what is advertised in the trade catalogue (see Fig. 4). Probably, during the use of the instrument, the front cover was lost and today the laser is uncovered. The laser in study is only accompanied by a power source/exciter (see Fig. 2). Perhaps this laser worked with the aid of a mount support, as recent lasers do today. This is the case of Newport company, the present owner of Spectra-Physics (Newport Corporation, no date).

Fig. 4 and **5** Spectra Physics 136 Series Catalogue. Adapted from: https://www.repairfaq.org/sam/brochures/SPOHLC1975/index.html and Laser model 136 from Deutsches Museum Munich (inv. N. DMM 2016 - 3T1) © Miguel Teixeira.

[2] Please see collections database: The National Museum of American History (no date) Laser eraser (1985.0144.01) Available online at:
http://americanhistory.si.edu/collections/search/object/nmah_713785 (Accessed May 10, 2018).

[3] Please see collection database: The National Museum of American History (no date) Helium-Neon Laser Discharge Apparatus (n.2008.0153.01) Available online at:
http://americanhistory.si.edu/collections/search/object/nmah_1339868 (Accessed May 10, 2018).

[4] Please see collection database: The Collection of Historical Scientific Instruments, Harvard University (no date) Early laser (n.1997-1-1585) Available at: http://waywiser.fas.harvard.edu/objects/12974/early-laser (Accessed May 15, 2018).

[5] This object is at Science Museum collections: Spectra-Physics 125 - high performance CW helium (n.1998-836). Available at: https://collection.sciencemuseum.org.uk/objects/co456347 (Accessed May 10, 2018).

The laser across the time (QIII)

In 1954, after research on microwave spectroscopy, Charles H. Townes (1915-2015) developed the first maser at Columbia University, USA. This is a close antecedent of lasers - the biggest difference is that masers amplify microwaves and laser amplify light[6].

In 1957, after the maser development, a conversation between Townes and Gordon Gould (1920-2005), a student from Columbia University led to the development of ideas about lasers that Gould put in practice in 1961, using a caesium light source[7]. In 1957, Charles Townes published an important theoretical that laid the basis for laser technology (Dwight 1984). Some years later, the ever first laser was made by Theodore Maiman (1927-2007) at Hughes Aircraft Company in 1961[8].

The foundation of a commercial company, Spectra-Physics, in 1961, is understood in what could be called the 'Laser Age'[9].Their founders were interested in different quantum electronic devices as rubidium vapor frequency, magnetometers and lasers. After establishing a joint venture with Perkin-Elmer, they developed the first commercial gas laser in March 1962 (Dwight 1984). In Spectra-Physics, the first gas laser was excited with a radio frequency power supply, "with a coil wound around the tube" (Dwight 1984). This situation changed when the company developed a new and improved power supply. In some years they changed from a 'traditional' to an industrial manufacturer, frequently called as "the world's first commercial laser company".

Who bought these lasers? According to Herbert M. Dwight, one of the company founder's, the costumers were industrial laboratories, government laboratories and educational institutions (Dwight 1984). Companies such as Xerox and Bell Laboratories were also costumers. Dwight considered that acquiring a complete laser instead of building one was important for buyers.

The growing interest for lasers is reflected in higher education institutions. The Antenna Laboratory (Peters, no date) from Ohio State University organised a symposium on lasers and their applications in 1962 (Aagard 1962). In this area, the research has a focus on atmospheric optical propagation and their relationship with laser system effects, among others (Long & Lewis 1962). In late 1960s, the Antenna Laboratory continued to organize courses related to laser propagation.

The first lasers were not visible. In 1962, scientists at Bell Laboratories discovered the He-Ne laser, the first visible (Bromberg 1991). These were challenging years for new

[6] Please see collection database: The National Museum of American History (no date) Maser Focusing Assembly (EM.323893). Available online at:
http://americanhistory.si.edu/collections/search/object/nmah_712778 (Accessed May 10, 2018).

[7] The National Museum of American History (no date) Experimental cesium laser component (EM.330385). Available online at: http://americanhistory.si.edu/collections/search/object/nmah_1323089 (Accessed May 10, 2018).

[8] The National Museum of American History (no date) Head Piece from Maiman Laser (EM.330050). Available online at: https://www.si.edu/object/nmah_712855 (Accessed May 10, 2018).

[9] After one publication by Schawlow and Townes in 1958, several teams start developing research on the field to build an optical maser. Institutions as Columbia University, TRG Corporation, Westinghouse laboratories, IBM, Hughes Laboratories and Bell labs were among the race to be the first. For further information please see: https://history.aip.org/history/exhibits/laser/sections/therace.html

discoveries in the field of laser technology. When Bell Labs developed the visible laser, Spectra-Physics was developing identical research with Perkin-Elmer (Bloom 1983).

The development of visible laser was a major event in laser's history. When the He-Ne laser appears, the popularity of laser technology increased. Spectra-Physics expand sales and duplicated their production. In 1963, the joint venture between Spectra-Physics and Perkin-Elmer came to an end and, until c.1980, Spectra-Physics was the number one in laser gas technology. For Dwight: "visible laser beam was almost irresistible to scientists and teachers" (Dwight 1984). From demonstrations in various laboratories in Europe to the interest of Honolulu University in this device, Spectra-Physics was the main player in He-Ne laser development and trade (Bloom 1983).

In the 1960s, laser research was conducted not only in US laboratories and universities but also in Europe. The laser community gathered in the Quantum Electronics Conferences (1959-1963), first in New York and Berkeley (U.S.A), then in Paris (France). The Conferences discussed the emergence of laser technology, from the initial Masers in United States Navy Laboratory (Smiley 1963) and leading companies as Spectra-Physics discussing new He-Ne lasers (Bell et al. 1963) to new research developed in Europe as ruby lasers in United Kingdom (Adamson et al. 1963), and also Romania (Agirbiceanu et al. 1963) and Italy (Arecchi 1963), among others.

Germany was also engaged with laser research and Munich was an important academic and industrial centre. Siemens transferred its laboratories from Berlin to Munich after World War II, in 1949[10]. Siemens' researchers attended the 1963 symposium on quantum electronics and presented research on ruby masers (Gurs 1963) and lasers (Roess 1966). In terms of academic research, the Munich Technical University was developing laser research by 1964, namely solid state laser (Kaiser & Pohl 1964).

The range of scientific areas covered by He-Ne laser research is remarkable. From classroom demonstrations of photoelectric effect and measurement of laser beam waveleght (Castka 1976) to Zoology, where researchers used laser technology - Spectra-Physics 136 laser - to produce a diffraction pattern in a liquid solution at an Australian University (Fink et al. 1986). Even today, He-Ne laser technology has applications in alignment, metrology, particle measurement, velocimetry and confocal microscopy (Newport Corporation, no date). The barcode readers are also a result of this technology.

What do we know about this He-Ne Laser? (QIV)

The pre-museum museum life of the Deutsches Museum's He-Ne laser is largely unknown. The laser had been at the Deutsches Museum Electronic Workshop in Munich for an unknown period – "long time" – when the curator Johannes-Geert Hagmann was approached by Workshop technicians. It was accessioned into the Museum collection in 2016.

The object labels show that the laser and power supply/exciter were both manufactured as a mass production instrument by Spectra-Physics Headquarters at Mountain View, California, U.S.A. The foundation of the company in 1961 (Dwight 1984), followed by a joint venture with Perkin Elmer that ended in 1963, combined with a trade catalogue

[10] The Forschungslaboratorium is a result of expansion of Siemens research facilities in 1920. Renamed in 1924 as "Forschungslaboratorium der Siemens & Halske AG und der Siemens-Schuckertwerke GmbH". See Nikolaus, K (2015) 110 years of central research at Siemens. Available at: https://www.siemens.com/history/en/news/1322_ct.htm

dated from October 1975, suggests a manufacture date between 1963 and 1975. Moreover, the power supply was specifically made for the European market, equivalent to 230 Volts and European line plug.

The circumstances of laser's arrival at Deutsches Museum Workshops, as well as its use there, require further research. Several hypotheses remain available: The possibility of a former order from Deutsches Museum to equip its workshops with a working tool or the connection to research activities developed by the museum in partnership with higher education institutes (J. Hagmann 2018, pers. comm., March 2).

Unfortunately, although I tried to get access to Spectra Physics archives, I didn't receive any reply until now. Tracking the serial number could be interesting to identify the year of production and the pre-museum history.

Conclusion

Gessner's model is important to organize information in a structured way and understand the multiple questions related to object-based research in historical studies. It provides a map to guide the research crossing some of the most important tangible and intangible properties of scientific instruments. However, it also requires crossing multiple sources – observation, iconographic, documental, and oral – and some of these sources are often absent in museum records and their identification requires time.

The main difficulty in this research was the absence of associated documentation regarding the laser biography (who acquired the laser? For what purpose? Until when was it used and what for?). At this point, it is not possible to match the laser with specific uses/experiments or scientists/institutions. Trade catalogues are a very important source – there was a 1975 catalogue – but they provide information about function and class, not the uses of the individual instrument.

What is the importance of this laser for the History of Science, globally and locally? Recent scientific heritage appears to be less visual attractive than older scientific instruments, although this object represents the beginning of laser mass production. As the first laser was produced in 1960, and the first He-Ne laser only 3 years later, this device was produced in the beginning of this technology that changed the world. With this object, we can create historical narratives about laser technology and explore the scientific principles that led to the development of lasers. The multiple applications in daily life give lasers an important status that a museum can explore in their exhibits.

Scientific instruments produced after World War II, as the case of He-Ne lasers, are considered as Recent Heritage of Science. Mass production of instruments in the 20th century led institutions to preserve only a small part, due to big size, industrial production, among others. In general, mass-produced instruments are not seen as important to a museum as pre-WWII scientific instruments (Lourenço & Wilson 2013). Moreover, often museums focus on 'iconic' objects by elite scientists (e.g. Nobel Prizes, scientific breakthroughs, prototypes), which they document quite well, giving less importance to non-elite users and practices (e.g. workshops, teaching objects, utensils, tools). A good example is the recently accessioned Theodore Maiman's laser by Deutsches Museum in 2015. As the first ruby laser to be build, and its association to a pioneer of laser technology, a press release was produced by the museum (Deutsches Museum 2015). One year later, when the Spectra-Physics laser entered in the museum collections, there wasn't any press release about that. This could be explained by the main concerns of recent heritage – the mass production and the apparently unknown biography of this object, without connection to the big scientists.

Documentation is important as complementary source. Research in museum archives could give different insights to the historian about the role of this object. Other approaches using oral history could give light about the uses and practices of lasers in the museum context. Further research must focus on the relation between scientists, researchers, universities and Deutsches Museum. Cannibalization is another threat to this kind of heritage. Old devices, out of work are used to replace pieces in similar devices. Scientific networks and knowledge transfer from Munich universities or the expertise in the museum workshop to deal with this instrument is just an idea, without factual sources. However, as a mass production and robust instrument, was probably intended to research or technical support in a laboratory environment.

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