Key Scientific questions in the definition of the SI unit of luminous intensity, the candela

25th Meeting of the CCU
- Introduction of **defining constant** for photometry, $K_{cd}$
  
  **luminous efficacy** of monochromatic radiation of frequency $540 \times 10^{12}$ Hz

- **Reformulation** of definition of the candela
  
  - (not a redefinition), to bring it in **explicit constant** form:
• $K_{cd}$ makes a direct link between photometric and radiometric quantities for monochromatic radiation of frequency 540 THz

<table>
<thead>
<tr>
<th>flux</th>
<th>illuminance</th>
<th>intensity</th>
<th>luminance</th>
</tr>
</thead>
<tbody>
<tr>
<td>lm $\leftrightarrow$ W</td>
<td>lx $\leftrightarrow$ W·m⁻²</td>
<td>cd $\leftrightarrow$ W·sr⁻¹</td>
<td>cd·m⁻² $\leftrightarrow$ W·sr⁻¹·m⁻²</td>
</tr>
</tbody>
</table>

• *Mise en pratique for the definition of the candela in the SI* (20 May 2019)
• BIPM report 05/2019: *Principles governing photometry* (20 May 2019)
• *Appendix 3 Units for photochemical and photobiological quantities* (20 May 2019)
The present definition serves very well all practical requirements for global trade, science and society.

However, still there is a key scientific challenge related to the fact the defining constant, linking the given photometric unit to the corresponding radiometric unit, has no fundamental character.
COMITÉ CONSULTATIF

DE PHOTOMÉTRIE ET RADIOMÉTRIE

9e SESSION — 1977

COMITÉ CONSULTATIF

DE PHOTOMÉTRIE ET RADIOMÉTRIE

8e SESSION — 1975
(3-5 septembre)
Success story: Photometry

Standard Photopic observer (CIE 1924)

Luminous efficiency

K_{cd} = 638 \text{ lm} \cdot \text{W}^{-1}

Wavelength (nm)

Luminous intensity (visual)

SI brochure
Principle governing photometry
\[ L = K_m \int L_{e,\lambda} V(\lambda) \, d\lambda \]
CIE Photometric standard observer

6\textsuperscript{th} session of CIE, Geneva, 1924

K. S. Gibson:
Visibility function

272 observers (UK, Japan, US)
Photometry – a success story

Radiometry & spectrophotometry

Current method

Psychophysic experiments

Perception model

\[ \int_{380}^{780} P_\lambda \cdot V(\lambda) \, d\lambda \]

Normalization activity
Photometry is the science of the measurement of light, in terms of its perceived brightness to the human eye.
Measurement of visual quantities

Photometry deals with visual quantities.
The measurand is not accessible by the measuring instrument
The measurand may vary from an observer to another
Human eye

- Lens
- Fovea
- Retina
- Optical nerve
- Rod
- Cone
We have 3 family of cones. Light that reaches the retina generates 3 signals in the cones, that depend upon the wavelength.

Cones (L M S)

- S(λ) with λ_max ≈ 440 nm
- M(λ) with λ_max ≈ 540 nm
- L(λ) with λ_max ≈ 570 nm
Measurement of perceptive quantities

Future method

Perceptive scale

Physical scale (measurable)

Perception models

Machine learning

Artificial intelligence

Radiometry & spectrophotometry

Image-based radiometry

Normalization activity

Standard observer

Individual observer

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Taking into account the progress done so far and foreseeable in vision science and AI, there could be in few years some changes in the photometric quantities because of a much better understanding of the luminous perception using the cone-fundamentals system.
This cone-fundamental based photometric system would need a new link between photometry (lm, cd, lx,...) and radiometry (W, W/sr, W/m2...).

This link and its nature are the key scientific challenges in the definition of the candela for the next future.