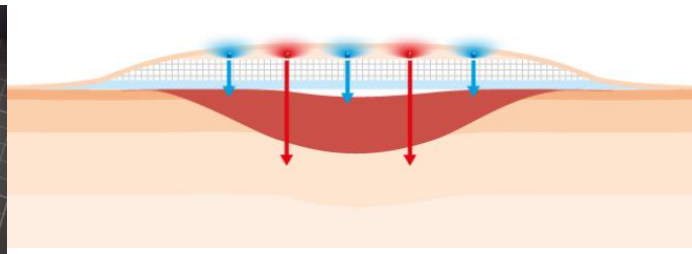
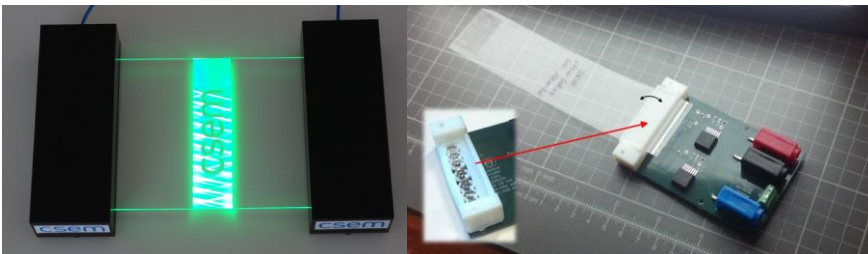


Wearable light management system for Light stimulated healing of Large area chronic wounds

David Kallweit, Nicolas Glaser, Jan Mayer, and [Rolando Ferrini](#)

SPIE Photonics West, 13.02.2016



CSEM at a glance

Our mission

Development and transfer of microtechnologies to the industrial sector – in Switzerland, as a priority – in order to reinforce its competitive advantage

- Cooperation agreements with established companies
- Creation of start-ups

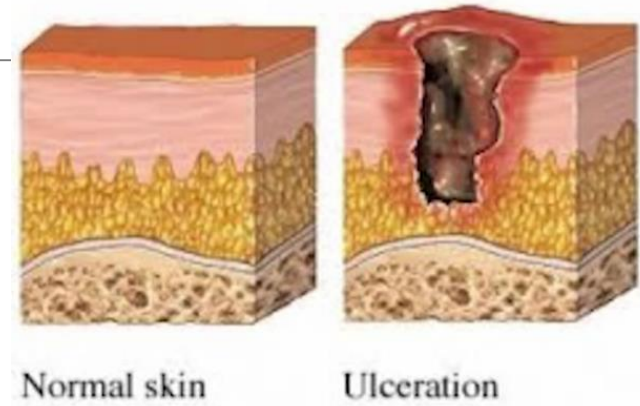


Outline

- Light stimulated healing of chronic wounds
- Miniaturized smart system for light stimulation and monitoring (MEDILIGHT)
- Building-blocks
- Wearable light management system
- Conclusions

Diabetic foot ulcer & Visible light therapy

- Large area chronic wounds caused by diabetes
 - Diabetic foot ulcer (DFU)
 - Affected people : 170 Mio worldwide
 - Costs : 40 billion € per year
 - Difficult to treat
- Therapeutic effects of visible light have been proven
 - **Blue light** (450-495nm) :
Antibacterial effects at the skin surface
 - **Red light** (620-750nm):
Growth of keratinocytes and fibroblasts in deeper layers of the skin



<http://www.americanfoot.com>

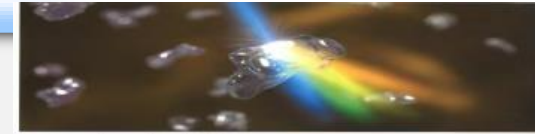
SSL systems on skin : state-of-the-art



* Ambulight/Ambicare (melanoma)



** Bluetouch (back pain)
Bluecontrol (psoriasis)



The chromophores of Lumi-Heal™ are illuminated with a multi-LED light. The topical Photo Converter gel (Lumi-Heal™) is enriched with fluorescent chromophores, which in the presence of an oxidant and light induces biophotonic therapy.
This non-invasive treatment is quick and easy to administer, and can be used across a variety of different types of wounds, thereby offering a convenient treatment option for patients and healthcare professionals alike.
Lumi-Heal™ is currently CE marked for the treatment of chronic and acute wounds, including DFUs, PUOs, VLUOs, Burns, and surgical wounds.

What is Biophotonics?
Generates an biological reactions triggered by light (similar to photosynthesis).
Uses a gel enriched with targeted chromophores (similar to chlorophyll).
Emulates a multi-LED lamp at peak wavelengths between 440-660 nm.
Resets a cascade of biological reactions that resets and reboots the healing process.
Offers an entirely new solution for treating wounds.

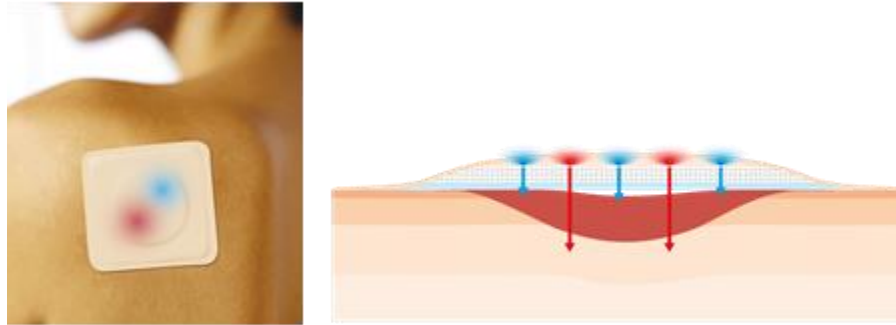
* LUMI-HEAL/KLOX
Photoconverter gel & LED
(chronic wounds)



* *Photodynamic methodology*

** *Photobiomodulation methodology (as in MEDILIGHT)*

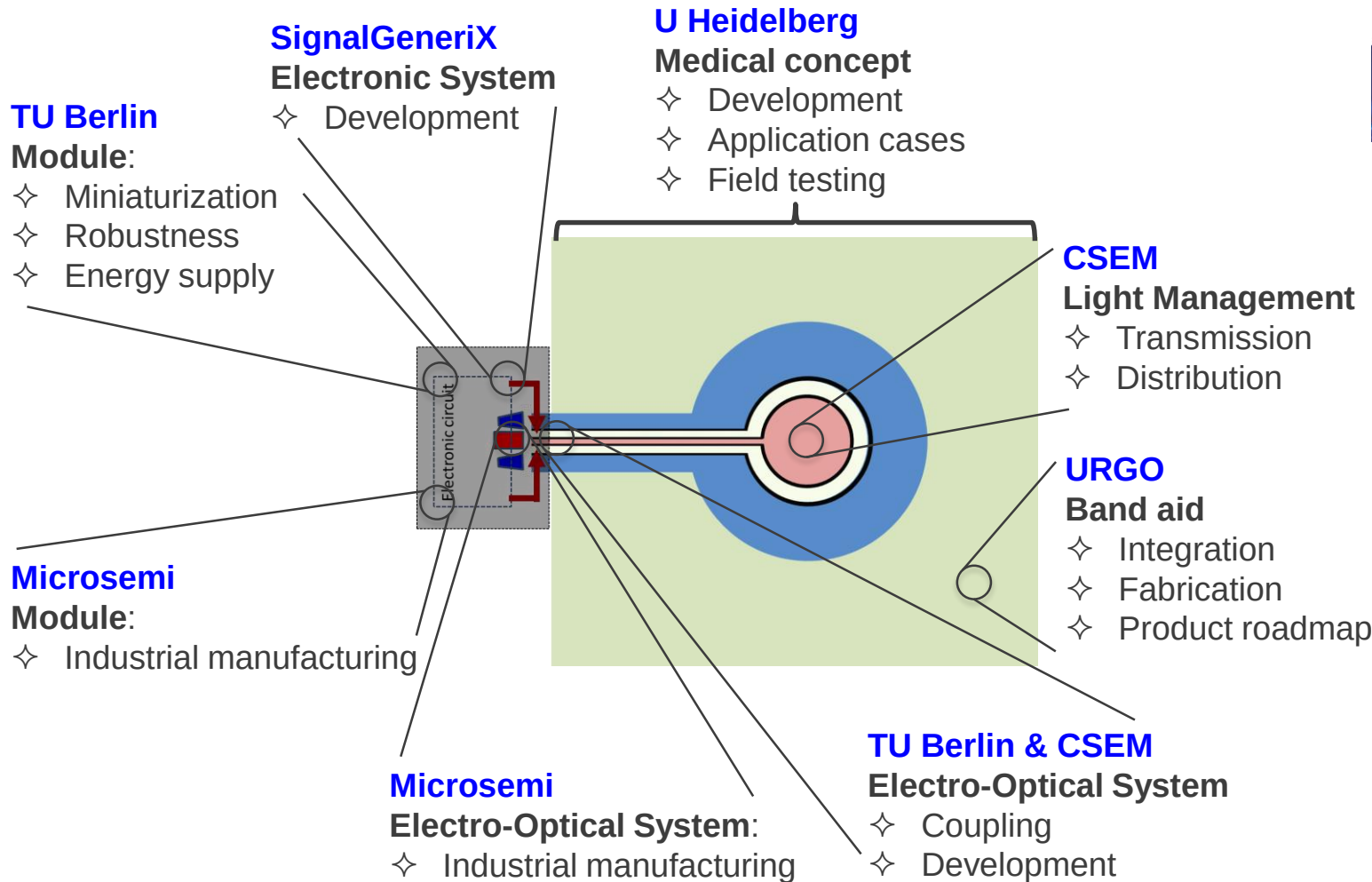
MEDILIGHT



Advanced wound healing

- **Fully integrated intelligent phototherapy band aid with**
 - Embedded light delivery
 - Sensors integrated in the wound dressing
 - Electronic control module
- **Temporal delivery schemes in accordance with the therapeutic policy**
 - exploitation of the proven biological impact of light irradiation on skin tissues
 - In-vitro & in-vivo studies
- **Highly integrated components – modularization**

Concept & Partners

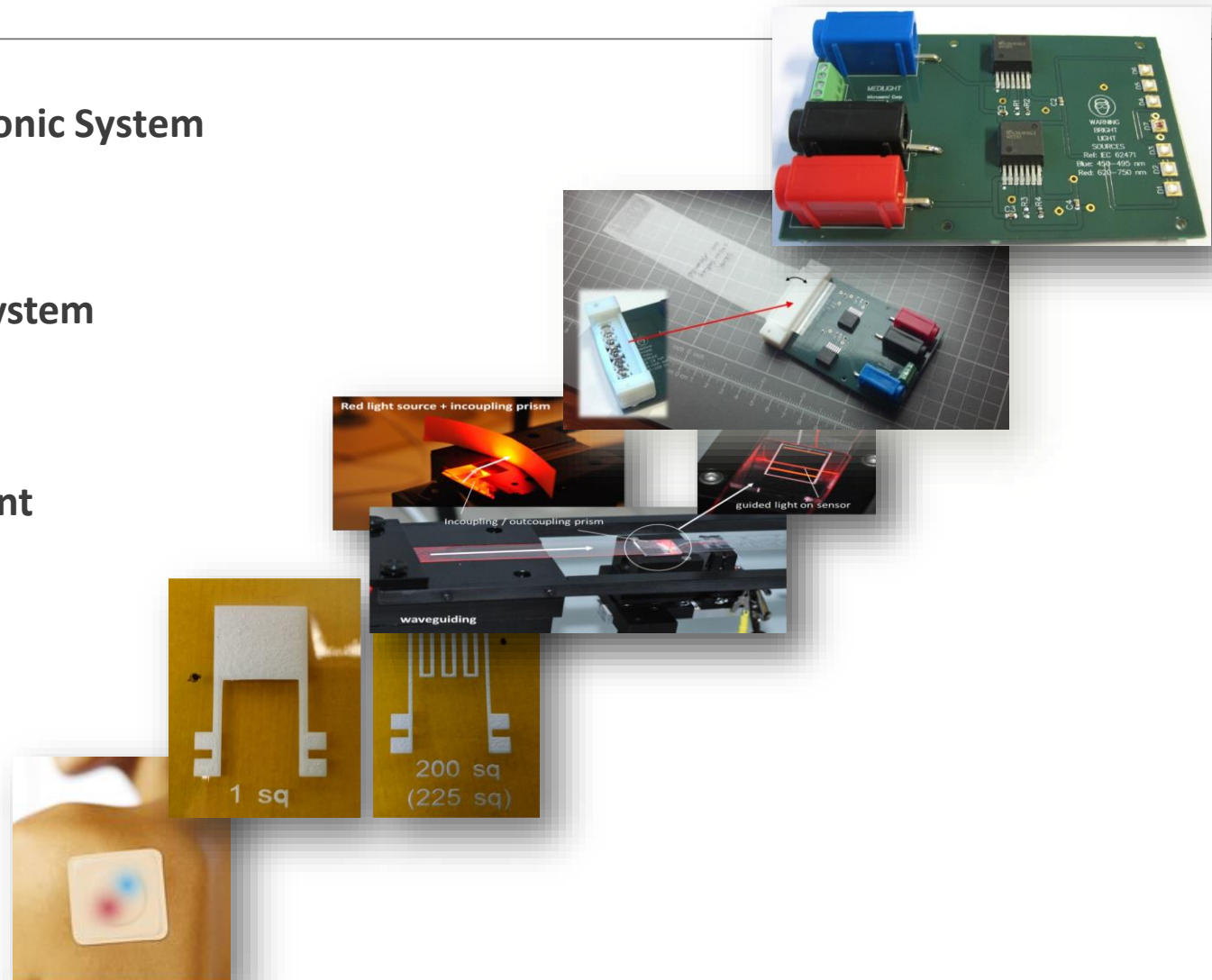


Objectives

- **Disposable wound dressing** with integrated light structures & electronic sensors
Target size = 13cm x 13cm
- **Highly integrated electronic module** (controlling & data acquisition)
Target size = 5cm x 3cm x 0.7cm
- **Illumination schemes** for the optimisation of the light therapy
- **Wireless device & software**
Recording the history of wound healing and provision of an individualised therapy
- **Testing:** In-vivo (pre-clinical) studies & first human trials

Building-blocks

- Module & Electronic System
- Electro-optical System
- Light management
- Sensors
- Band aid

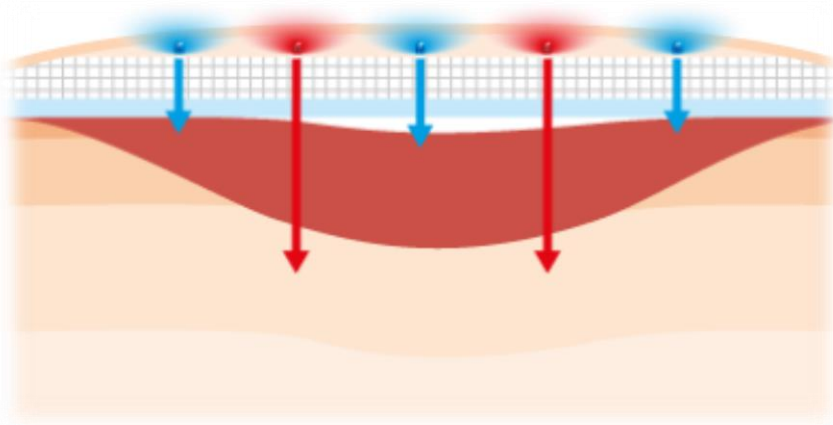


System design

The MEDILIGHT system consists of 2 components:

- Electronic module
- Wound dressing (**disposable**)

Electronic Module

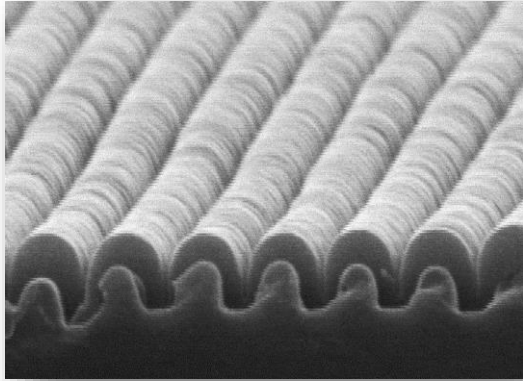


- ✧ Rechargeable battery

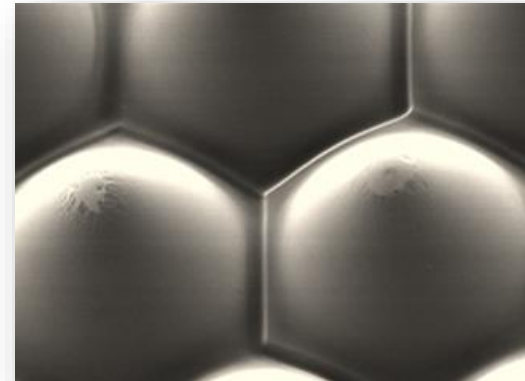
Wound Dressing

- ✧ Flexible large area optical waveguide
- ✧ Light management structures
 - Diffraction gratings (incoupling)
 - Diffusers (outcoupling & beam-shaping)

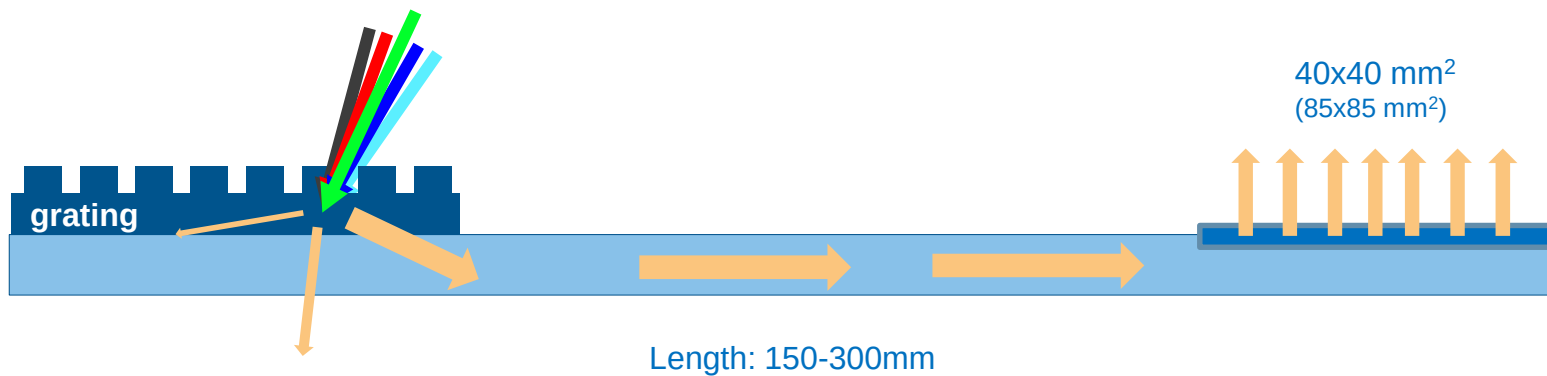
Light management system



Diffraction grating (light incoupling)

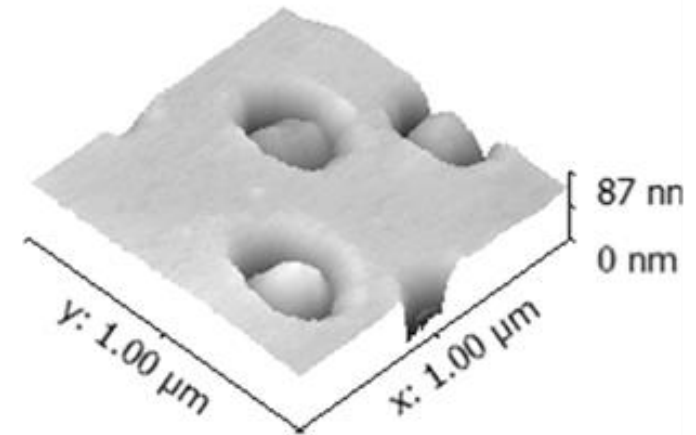


Diffusing microstructure
(light outcoupling & beam-shaping)

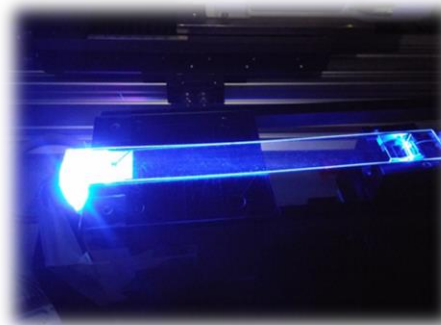
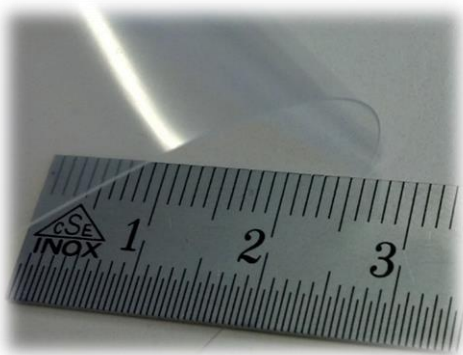


Waveguide : Material selection

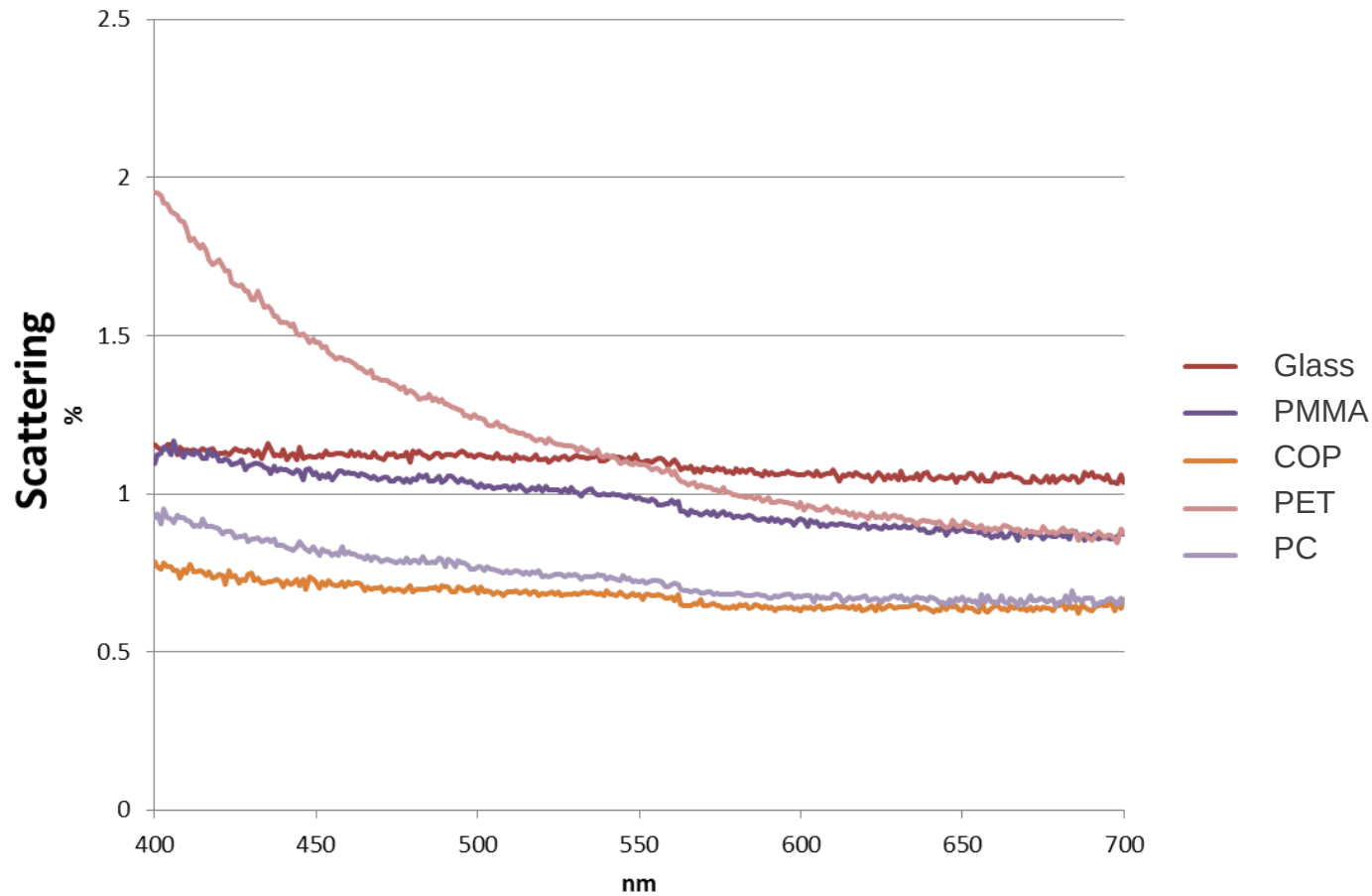
- **Target properties :**
 - high optical transmission
 - low scattering
 - good surface quality
 - highly flexible / bendable
 - insensitive to humidity (swelling, etc.)
 - easy to be embossed / injection molded
- **Different materials** were tested :
PET, PMMA, PC, COP, etc.
- **Thick glass slabs** were adopted as optical reference



Example: Surface of a measured PMMA sample

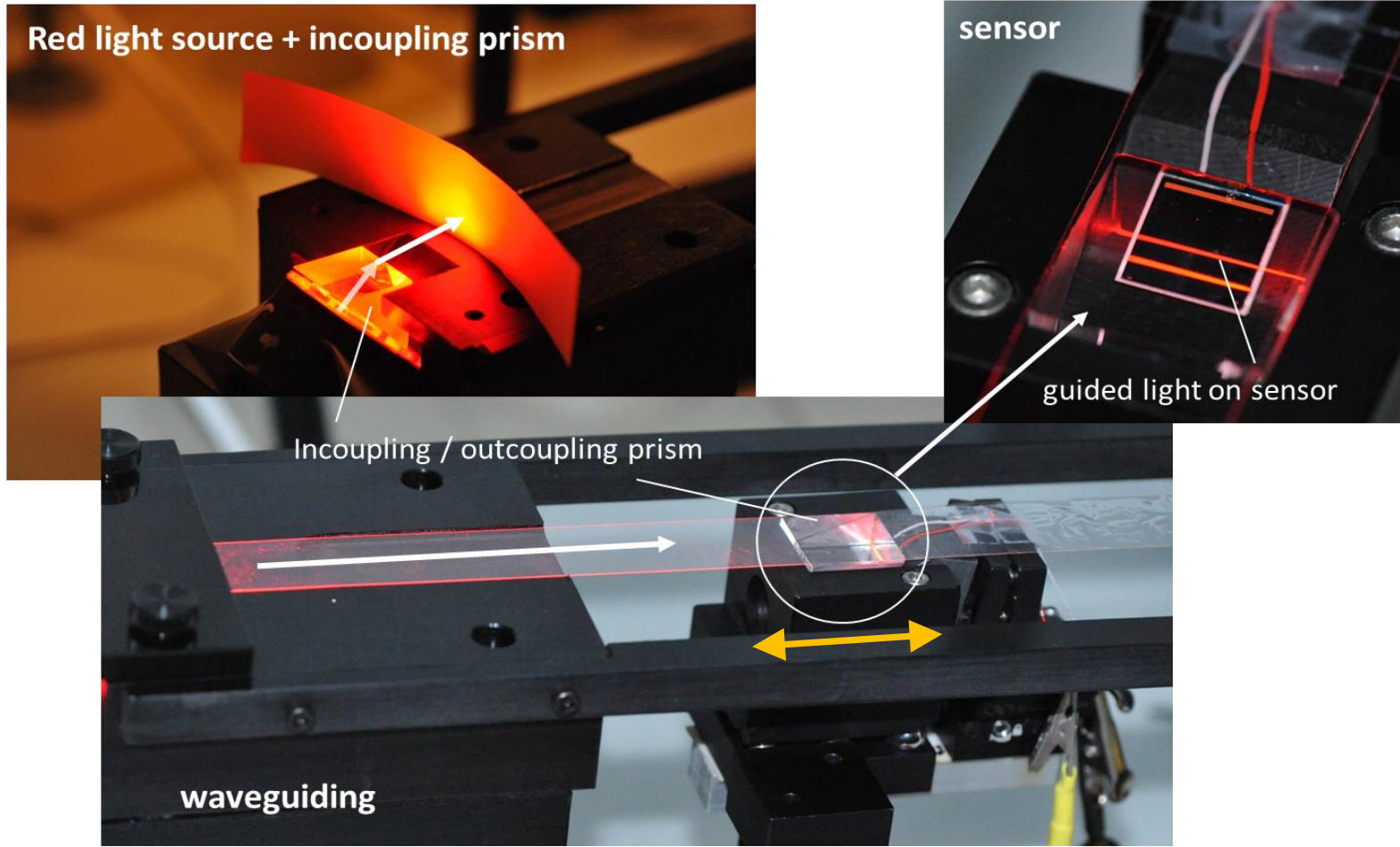


Waveguide : Light scattering

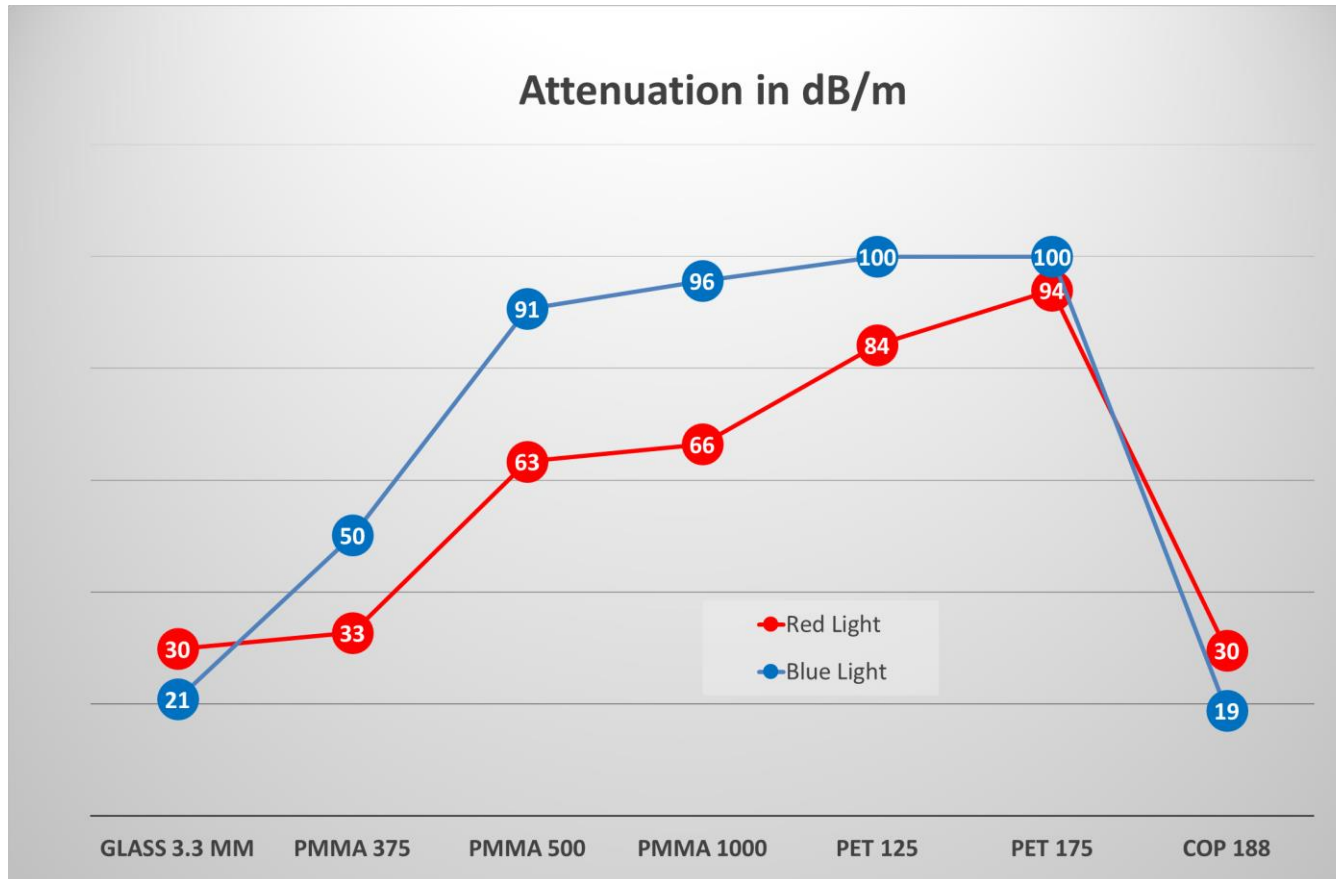


COP (188um) shows the lowest scattering

Waveguide : Measurement set-up



Waveguide : Propagation losses

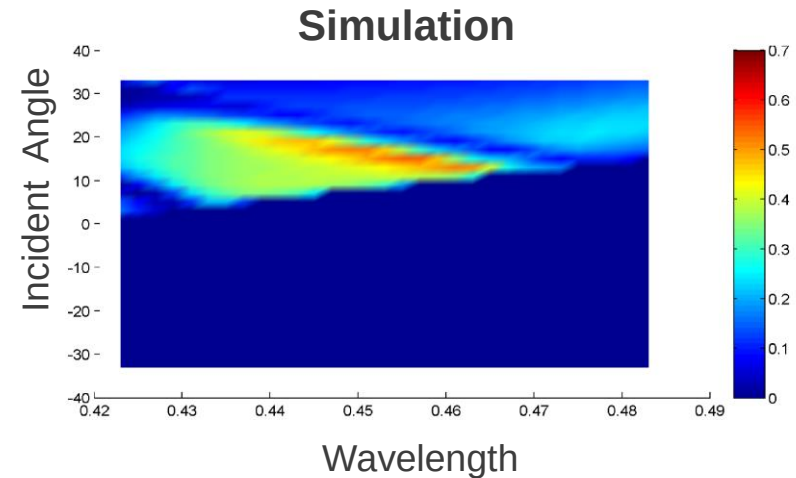
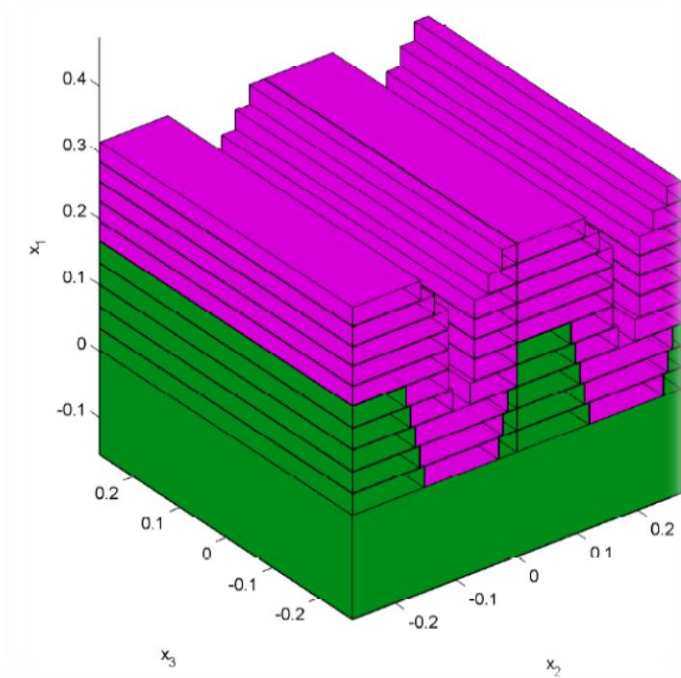


COP selected for its high optical transmission & insensitivity to humidity

Property of the MEDILIGHT Consortium

Incoupling gratings : RCWA design

BLUE



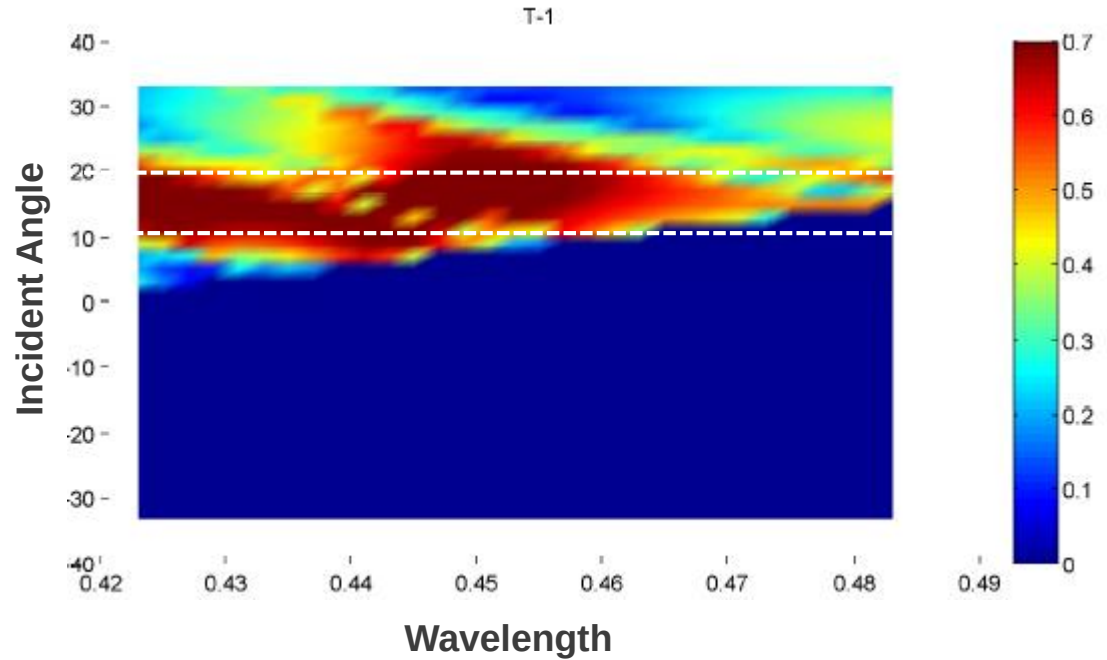
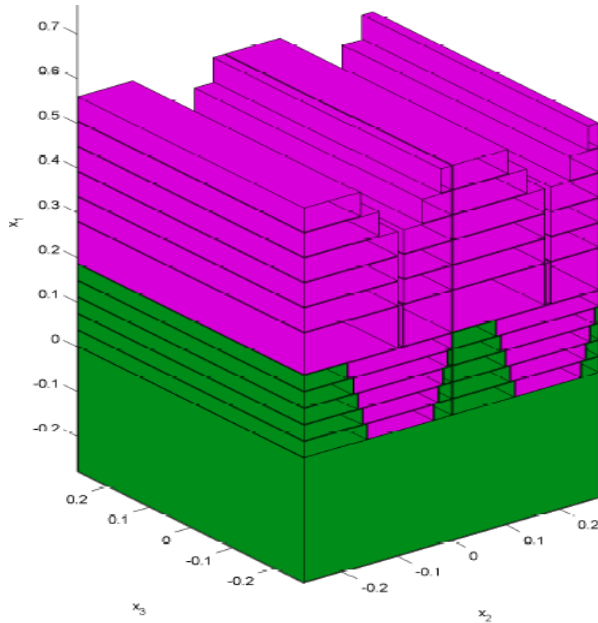
Measurement

Angle (deg)	T-1
11	24.6%
12	25.0%
13	25.3%
14	24.8%
15	24.5%

- **Calculated maximum diffraction efficiency in T-1 = 50%**
(at 440-465nm)
- **Measured diffraction efficiency = 25%**
(deviation of the fabricated profile from the simulation model)

Incoupling gratings : High-refractive index coating

BLUE

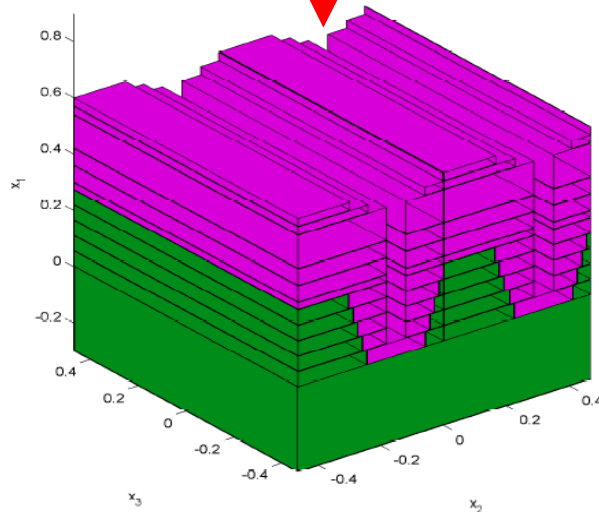
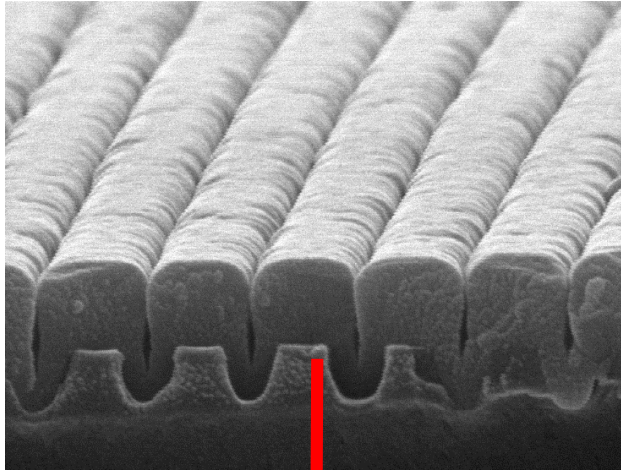


Increasing the thickness of the high-refractive index coating

- The theoretical maximum diffraction efficiency was increased **up to 70% at 10-20°**
- **The angle dependence is reduced** (higher acceptance angle)

Incoupling gratings : Fabrication

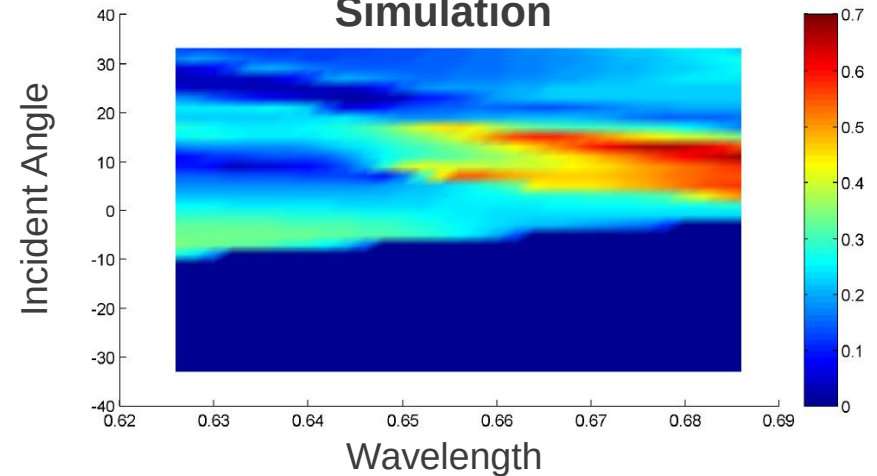
RED



Measurement

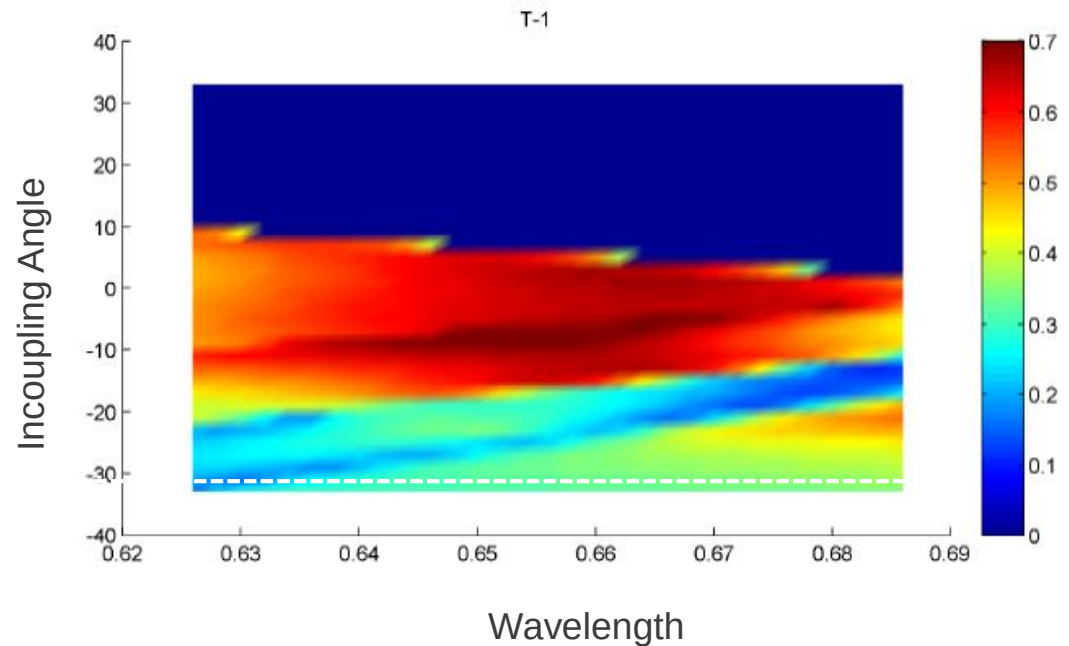
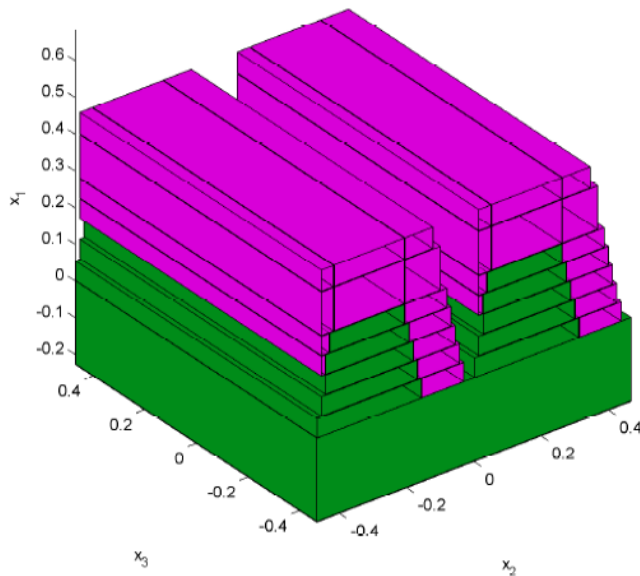
Angle (deg)	T-1
0	0.6%
3	7.7%
7	20.1%
8	36.6%
9	60.9%
10	61.0%
11	53.3%
12	45.4%
13	38.2%
14	35.3%
15	30.4%

Simulation



Incoupling gratings : Optimisation

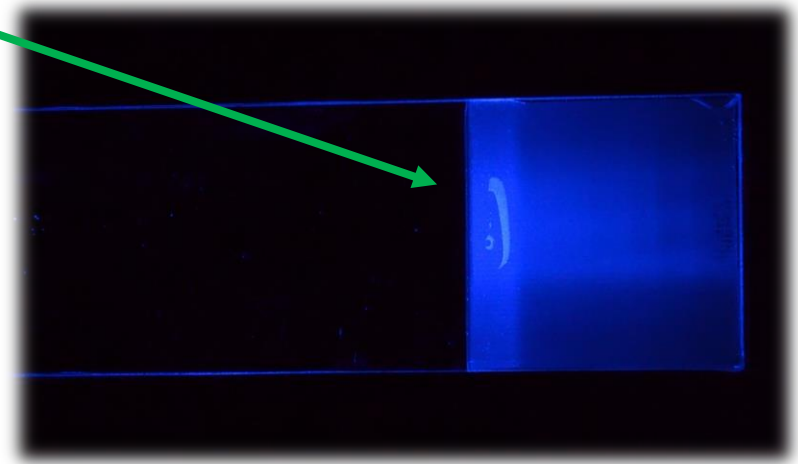
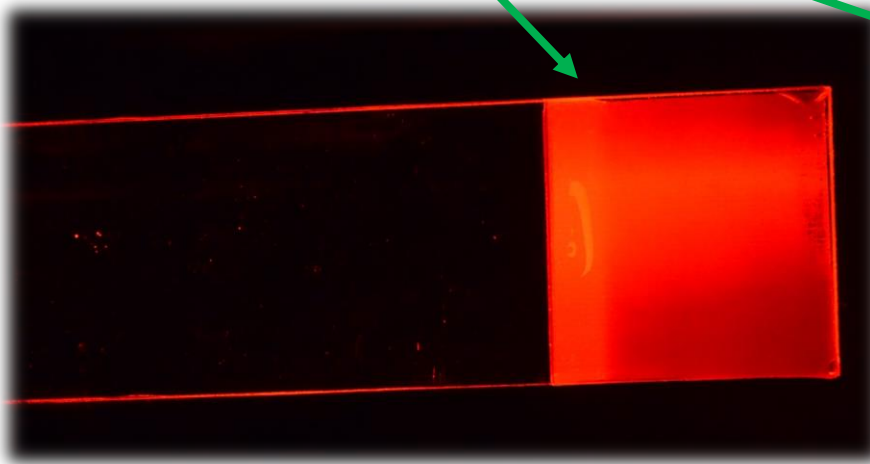
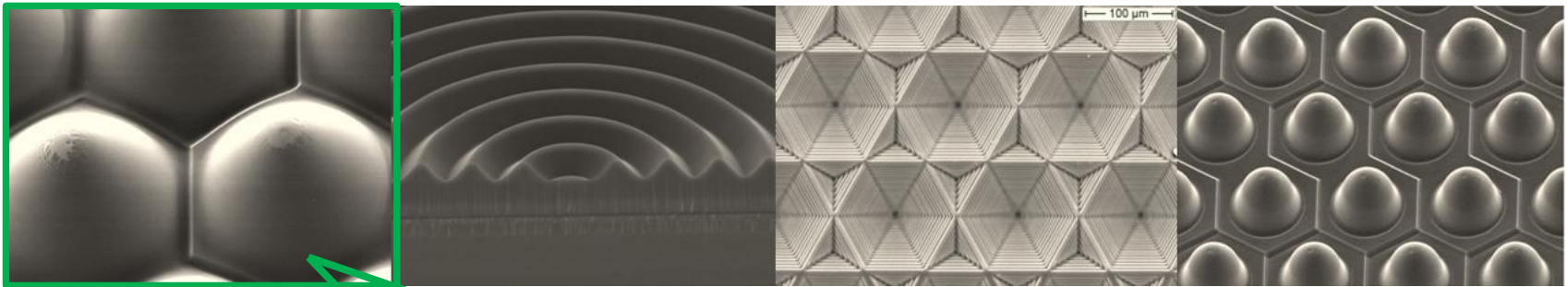
RED



Angular evaporation of the high-refractive index coating

- Maximum efficiency for the T-1 diffraction order at **normal incidence** ($\alpha_{in} = 0^\circ$) with **high angular tolerance**

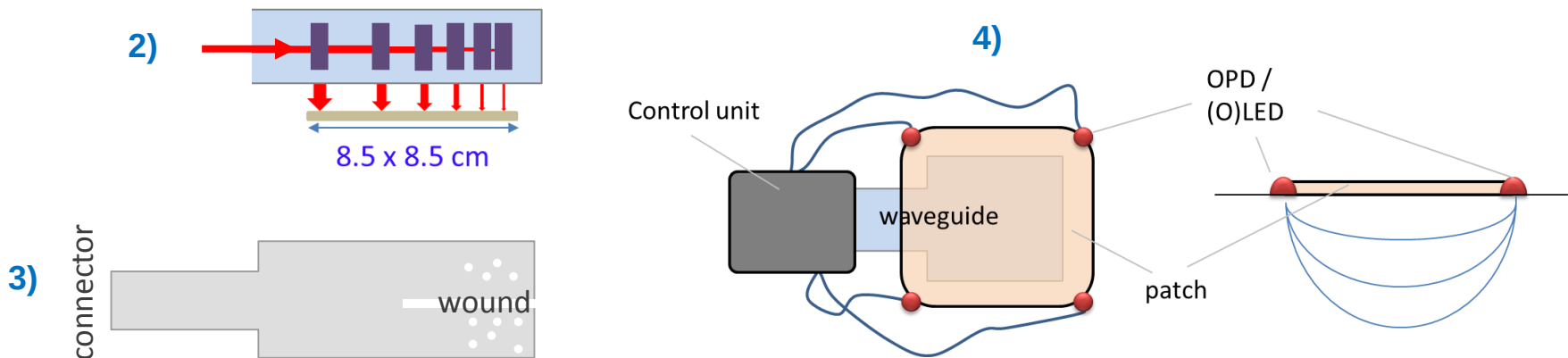
Outcoupling diffusers



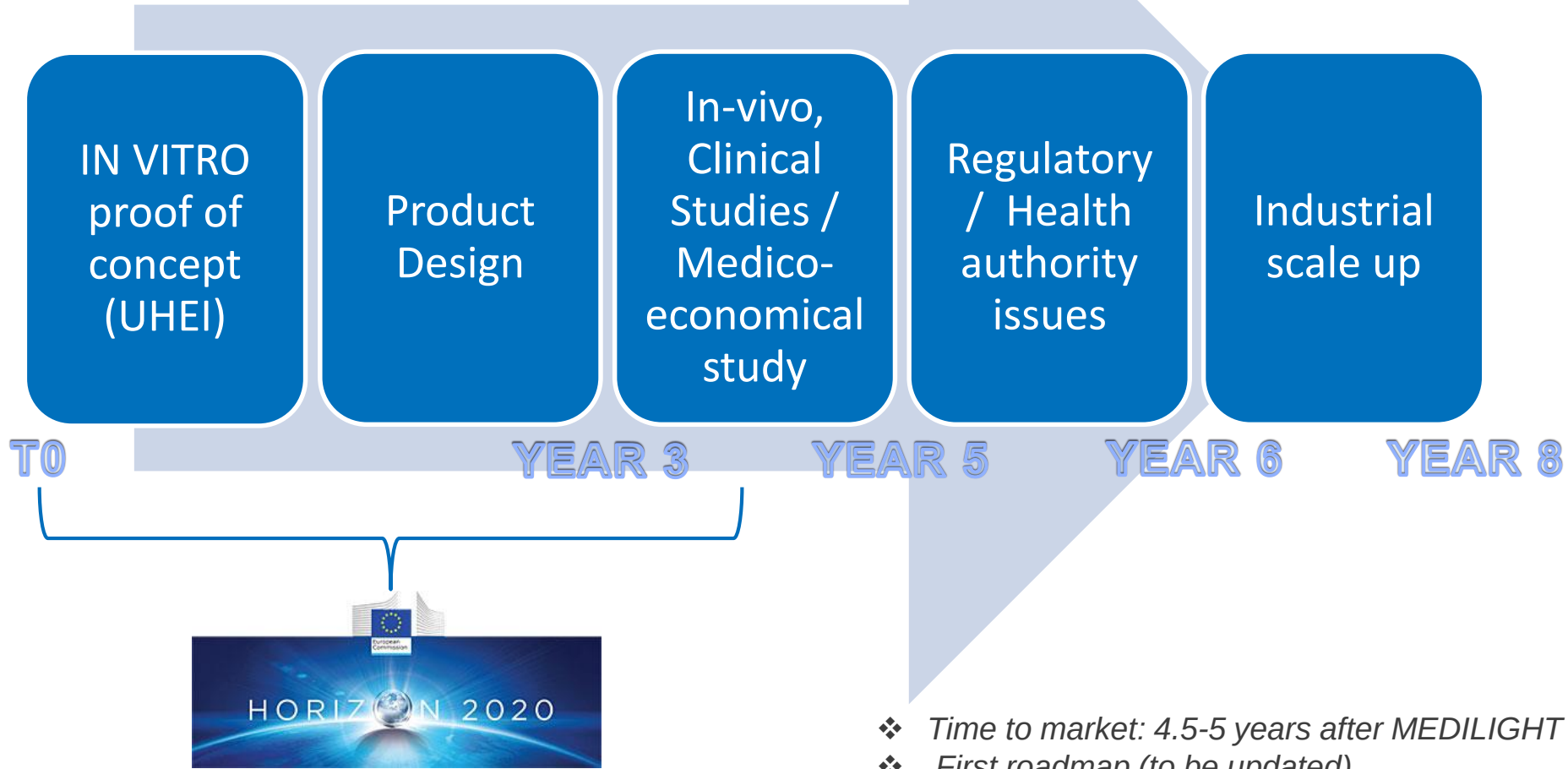
Property of the MEDILIGHT Consortium

Light management : Status & Outlook

1. Total light guiding efficiency is currently comparably low
2. Homogenous illumination of the wound area
3. Waveguide shape: holes, «fingers», etc. allowing the wound to breath
4. Integration of sensors (temperature and oxygenation)
5. Possible alternative concepts to be evaluated

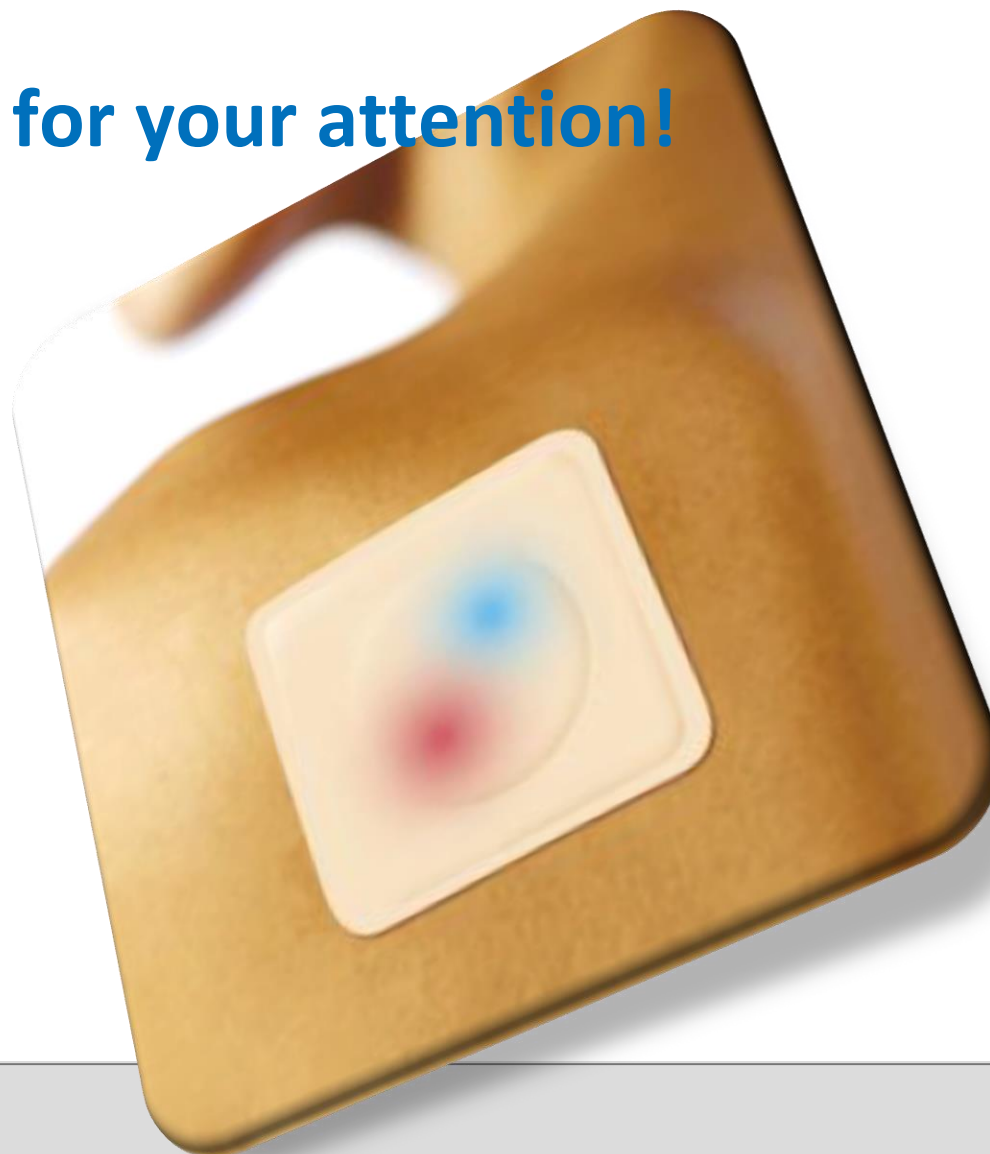


Conclusion & Roadmap

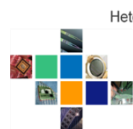


- ❖ *Time to market: 4.5-5 years after MEDILIGHT*
- ❖ *First roadmap (to be updated)*
- ❖ *Value chain partners identified*

Thank you for your attention!



Acknowledgements:



Heterogeneous
Technology
Alliance

SWISS PHOTONICS

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