AOP100-48 (Invited)	**Effect of hepatic vein on gold-nanoparticle-mediated-hyperthermia in liver cancer**	Mandana Jalali University of Duisburg-Essen (Germany)

Paper AOP100-48

Effect of hepatic vein on gold-nanoparticle-mediated-hyperthermia in liver cancer

Authors: M. Jalali, University of Duisburg-Essen (Germany); P. Mertin, Ruhr University Bochum (Germany); A. Rennings, D. Erni, University of Duisburg-Essen (Germany)

Gold-nanoparticle–mediated–hyperthermia is a non-invasive, target-based cancer treatment with significantly reduced side effects compared to conventional treatments. In this work, a simulation platform for gold-nanoparticle-mediated-hyperthermia is set up and is used to investigated the effect of the hepatic vein in vicinity of the tumor in case of liver cancer. An array of 80×20×20 nm3 gold nanorods with 800nm periodicity is considered and illuminated with 38 Wcm-2 860nm laser, which is the plasmonic mode of the corresponding nanorods. The geometrical shape and size of the nanoparticle is designed in a way that the plasmonic mode is located within the first near infrared window (650nm-900nm) with minimum light-tissue interaction that allows light to effectively penetrate into the body. The temperature increase within the tumor is calculated for the two cases of tumor location in the middle of the liver and in vicinity of the liver hepatic vein. In order to reliably account for convective cooling through the vein, the underlying heat convection coefficient is calculated based on energy and motion equations for Navier-Stokes fluid with laminar blood flow when only a portion of the vein is heated. The mentioned arrangement of nanorods is capable of 13º temperature rise within the liver when the tumor is in the middle of liver. However, when the tumor is located near the hepatic vein only about 3º temperature raise is achievable, as the convective heat transfer through the blood flow causes accelerated cooling and consequently the cells would not be ablated.

Effect of hepatic vein on gold nanoparticle-mediated hyperthermia in liver cancer

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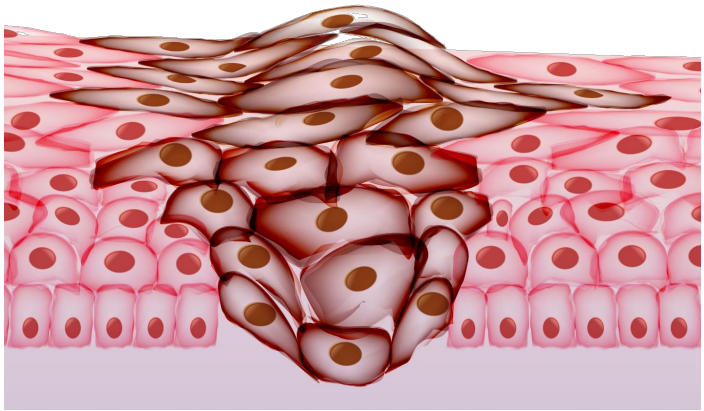
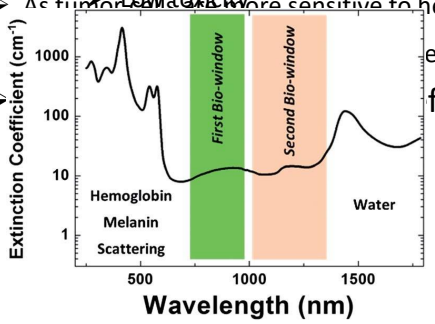
[https://www.123rf.com]



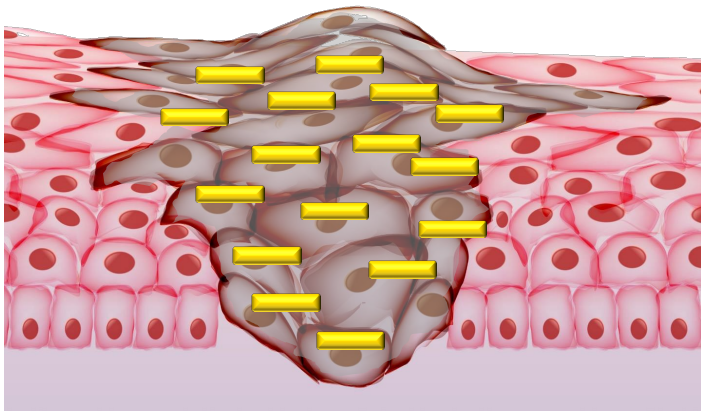
Gold nanoparticle-mediated hyperthermia

- Non-invasive
- Non-invasive
- Nanoparticles are injected within the tumor
- They are illuminated with a laser light
- Target-based
- As tumor cells are more sensitive to heat
- e
- ffects
  - High absorption cross section
  - Low toxicity

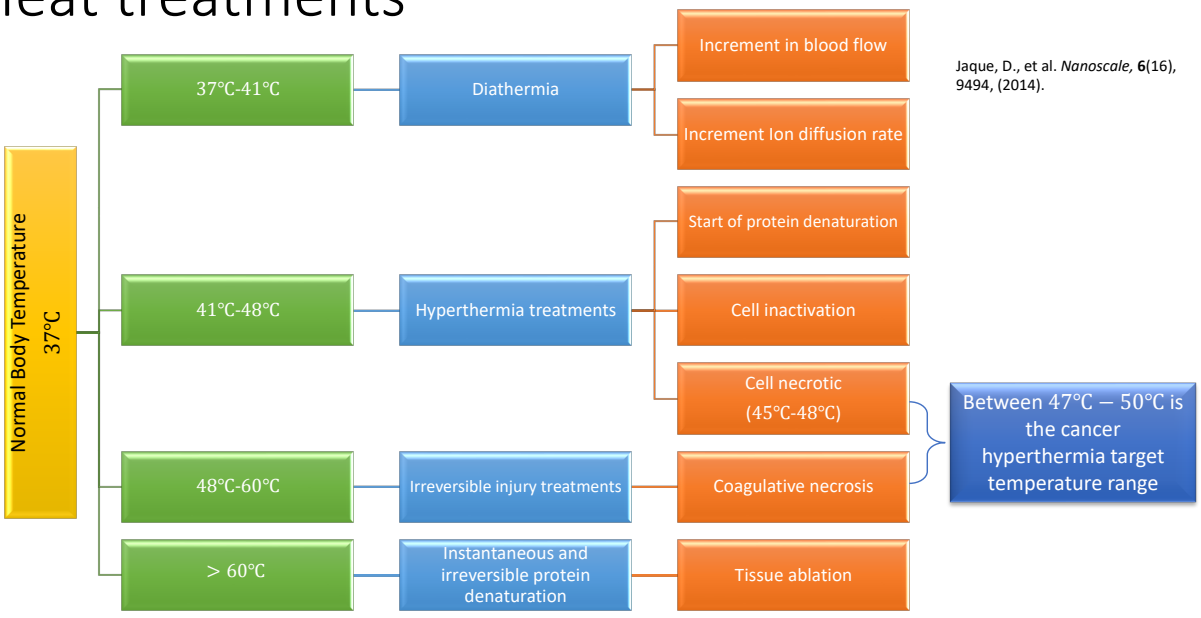


Jaque, D., et al. *Nanoscale,* **6**(16), 9494, (2014).

Laser illumination



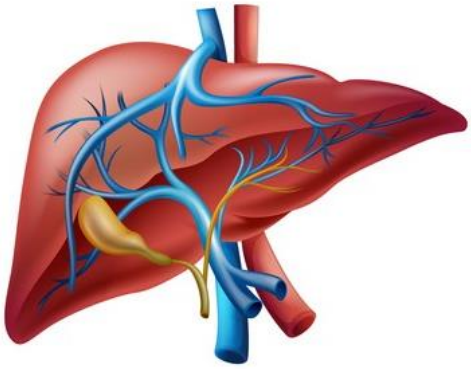
Heat treatments



Jaque, D., et al. *Nanoscale,* **6**(16), 9494, (2014).

Effective design

- Au-NPs plasmonic excitation
- Absorption efficiency $\Phi_{\text{abs}} = \frac{\alpha_{\text{abs}}}{\alpha_{\text{ext}}}$
- Laser power and wavelength range
  - CW laser: $38\,\frac{\text{W}}{\text{cm}^2}$, $\lambda = 868\text{nm}$
- Nanoparticle density
- Tumor position



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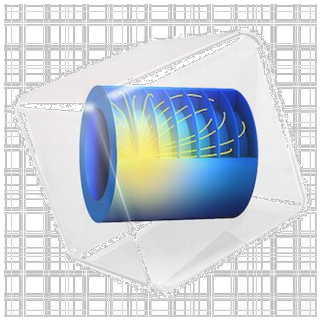
Simulation scenario

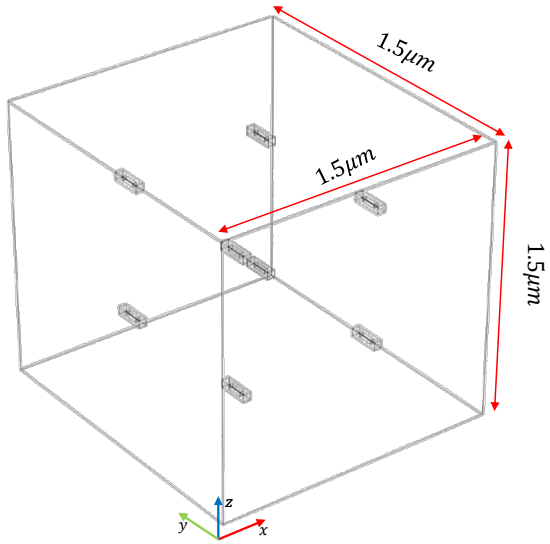


- Multiphysics simulation in Finite Element Method (FEM) software *COMSOL Multiphysics using:*
  - *Wave Optics Module*
  - *Heat Transfer Module (Bio Heat Transfer)*

Plane wave is illuminated to the pNPs at the optimized excitation wavelength → Heat transfer in the liver tissue and temperature enhancement → Account for cooling through blood flow

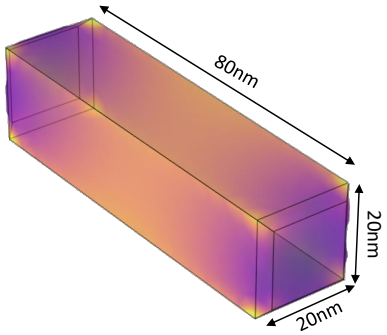
Simulation scenario

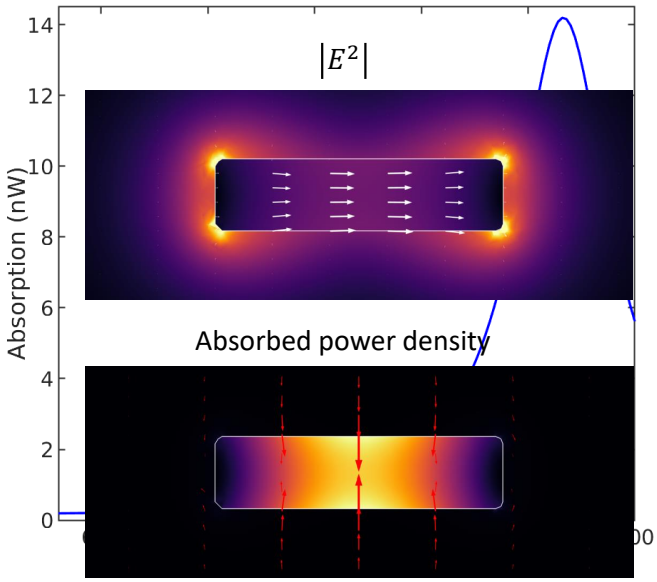
- 3D periodic NPs arrangement is considered
- Each NP acts as a heat source
- For the ambient medium, the mean values for liver tissue are taken into account
- The tumor is located in vicinity of capillary veins
- The effect of vein presence is taken into account through appropriate heat convection coefficients



Au-NP design

- Plasmonic excitation at longer wavelengths
- Relatively high absorption efficiency





❖ Plasmonic excitation at 868nm

Heat transfer in liver

Heat transfer within the body is mainly convection through the blood flow.

Convective heat coefficient:

$$\bar{h} = -\frac{\rho C_p \bar{u} b}{a} \log \frac{T_s - T_{bl1}}{T_s - T_{bl0}}$$

ρ	blood density
C_p	specific heat
b	vein diameter
a	length of heated region
$\bar{u}$	mean blood flow velocity
T_s	maximum temperature raise
T_{bl0}	constant blood temperature
T_{bl1}	temperature at the vein outlet

Consiglieri, L., et al. Phys. Med. Biol. **48**(24), 4125, (2003).

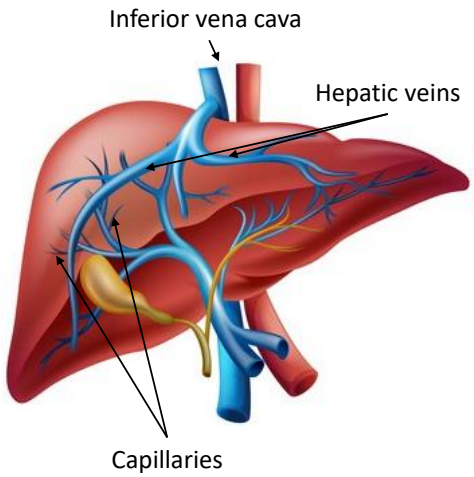
Liver anatomy

- Main veins in liver
  - Inferior vena cava

    $b \sim 1.7\text{cm}, \quad \bar{u} \sim 10 \frac{\text{cm}}{\text{s}}$
  - Hepatic veins

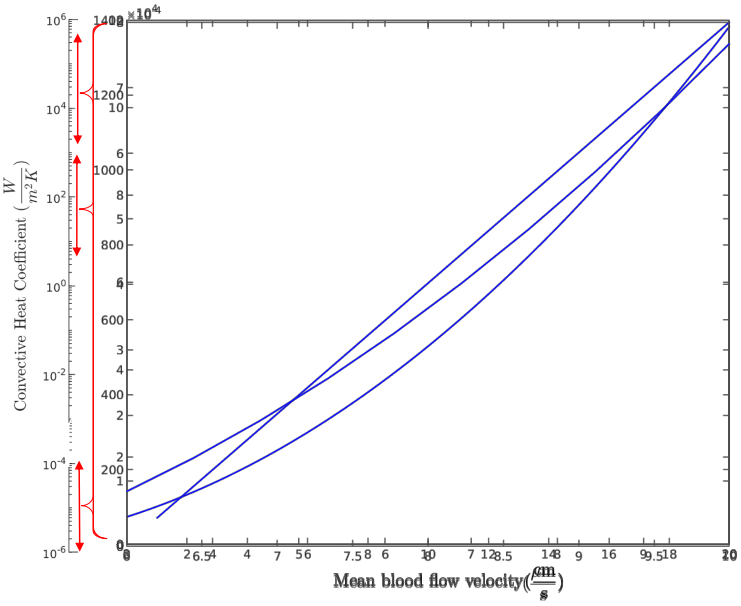
    $b \sim 0.3\text{cm}, \quad \bar{u} \sim 3 \frac{\text{cm}}{\text{s}}$
  - Capillaries

    $b \sim 0.0110\text{cm}, \bar{u} \sim 10 \frac{\mu\text{m}}{\text{s}}$

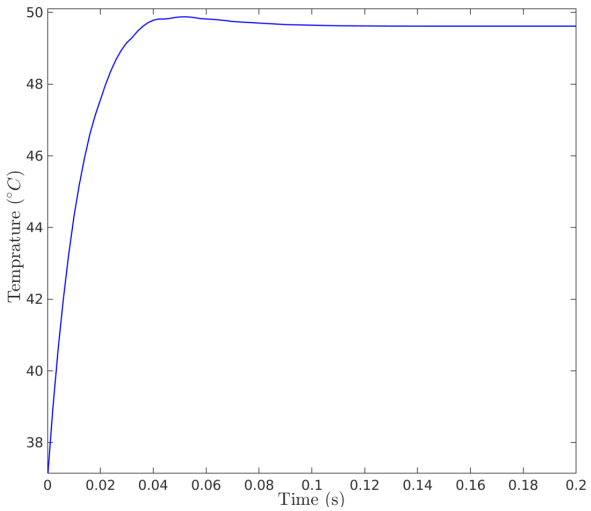


Convective heat coefficient

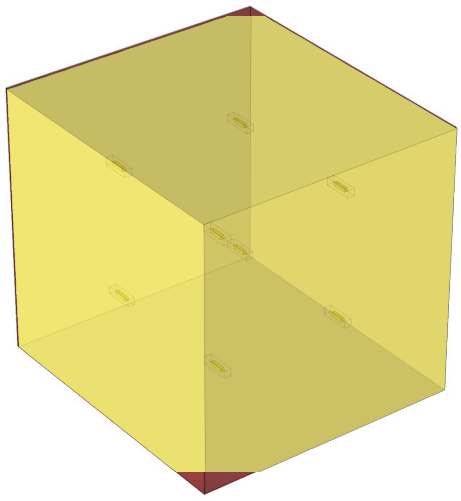
- Inferior vena cava
- Hepatic veins
- Capillaries



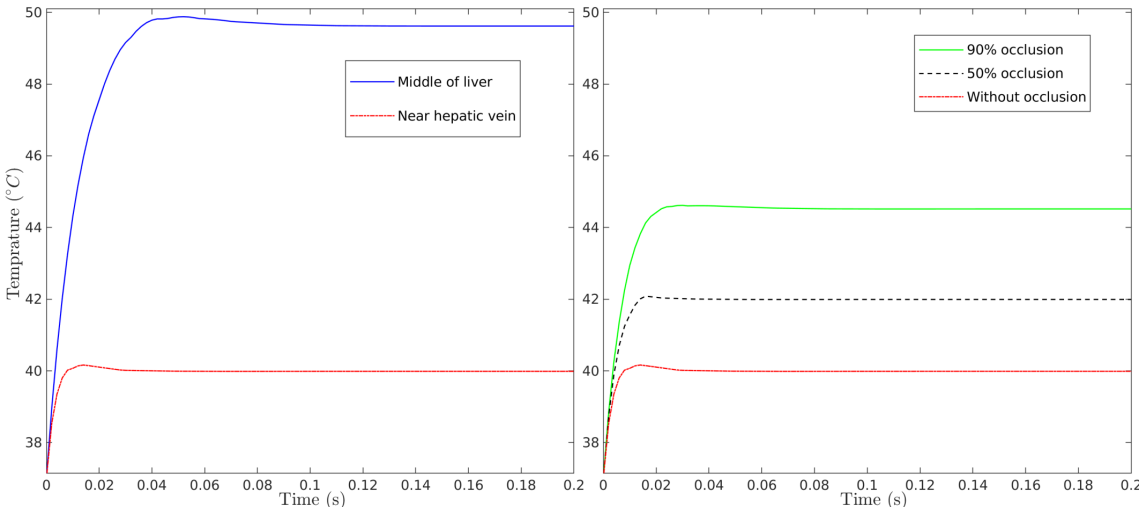
Tumor away from hepatic veins



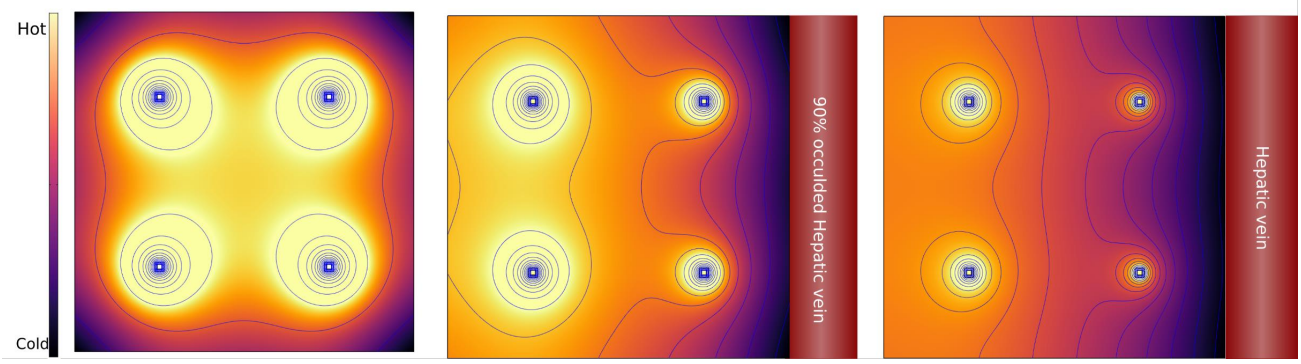
After 2min



Tumor near the hepatic vein



Temperature plane



Conclusions:

- ✓Although the pNPs determine the amount of generated heat within the tissue, temperature increase is highly dependent on the tumor position and the organ anatomy.
- ✓For each type of cancer, the gold-mediated hyperthermia should be specifically designed.
- ✓When the tumor is located near main veins, the therapy can only be used as a complementary treatment.

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Thanks for your attention

Questions?

https://www.ate.uni-duisburg-essen.de/index.htm

Call for Papers

The Portuguese Society for Optics and Photonics is organizing the IV International Conference on Applications in Optics and Photonics, AOP2019, which will be held in Lisbon, Portugal, on May 31 to June 4, 2019.

Upon the major success of SPOF' first three conferences - AOP2011 in Braga (www.optica.pt/aop2011), AOP2014 in Aveiro (www.aop2014.org), and AOP2017 at the University of Algarve in Faro (www.aop2017.org) – the periodicity of the conference was changed to biennial and therefore this next conference will take place at the University of Lisbon in 2019.

In the enthusiastic open and friendly environment that characterize SPOF' conferences, this forum will be an excellent opportunity to further foster the establishment of the widest range of cooperation projects and relationships with colleagues and institutions from Portugal and from all around the world. Open to contributions in all domains of Optics and Photonics and application' fields, with this conference we expect to review the state-of-the art in these subjects and to foresee and discuss the future of research in Optics and Photonics. Twenty five plenary and keynote lectures by world renowned researchers in all fields of optics and photonics, sets the quality standards of a varied and exciting scientific program. At the exhibition area we expect to have also boots and presentations of research labs and industries in order to promote and facilitate the setting-up of future new collaborations. A special space will be reserved for photonics spin-offs and young companies and entrepreneurs. The participation of students is encouraged with reduced fees support and several awards to the best works presented provided with the support of ICO, SPIE, EOS, HSCI and SPOF. Several prizes will be awarded. As it is tradition in our AOP conferences, an enjoyable social program will be organized further contributing to the setting up and cementing of long lasting friendship and cooperation relationships.

Peer-reviewed accepted papers will be published by SPIE in an ISI/SCI indexed proceedings book. Selected papers will be published on Special Issues of MDPI journals "Coatings" and "Photonics". Revised versions of the manuscripts published at the AOP2019 proceedings book are eligible to be submitted for publication at the OPA journal.

Important dates

Abstract Submission Deadline: January 18, 2019
Early Registration Deadline: March 15, 2019
Full Paper Submission Deadline: April 30, 2019

Organization

SPOF
Portuguese Society for Optics and Photonics

International Commission for Optics
Commission Internationale d'Optique
Territorial Committee of Portugal

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Cooperating organizations

International Commission for Optics
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Cooperating organization

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SOFE

SPIE Student Chapter
Univ. of Porto

OSA University of Aveiro Student Chapter

www.aop2019.org

optica@aop2019.pt

We are looking forward to welcome in Lisbon, for a most enjoyable and gratifying week, the Optics and Photonics community and our friends from all over the world!

4th International Conference on Applications of Optics and Photonics

AOP 2019

Chairperson

Manuel Filipe P. C. M. Costa (University of Minho, Portugal)

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Orlando Frazão (University of Porto)

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Optics and photonics education, outreach and societal issues
Manuel Filipe Costa (University of Minho)

Other topics
João Pinto Coelho (University of Lisbon)
Alexandre Cabral (University of Lisbon)

Plenary and Keynote Lecturers

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Katarina Svanberg (Lund University, Sweden / South China Normal University, China)
Elvira Fortunato (Universidade Nova de Lisboa, Portugal)
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