Supporting information for:
The role of gold nanoparticle morphology and coupling on optical breakdown during picosecond pulse exposures

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Theory and parameters used in the model

Electromagnetic field interaction

Several physical phenomena need to be fully coupled in order to fully characterize a low density plasma formation in the vicinity of gold nanoparticles and their assemblies in aqueous medium. The electric field, $E$, produced in and around gold nanoparticles was divided into incident electric field, $E_{\text{inc}}$, and scattered field, $E_{\text{sca}}$: $E = E_{\text{inc}} + E_{\text{sca}}$. $E_{\text{inc}}$ was imposed on the domain boundary and $E_{\text{sca}}$ was calculated in the domain using Helmholtz wave equation (details on the individual symbols and constants used in the theory and model can be find in the Table S1):

$$\nabla \times \nabla \times E_{\text{sca}} - \omega^2 \varepsilon_0 \mu_0 \varepsilon E_{\text{sca}} = 0,$$  \hspace{1cm} (1)
where $\varepsilon$, is the size-dependent dielectric constant for gold. It is given by:

$$
\tilde{\varepsilon}(\omega, L_{\text{eff}}) = \varepsilon_{\text{bulk}} + \frac{\omega_p^2}{\omega^2 + i\omega\gamma_0} - \frac{\omega_p^4}{\omega^2 + i\omega \left(\gamma_0 + \frac{\Delta n}{L_{\text{eff}}} + \frac{n\nu_{\text{au}}}{\pi}\right)}.
$$

The incident light was polarized along the $y$-axis (the longest axis of the nanostructure) and travelled along the positive $z$-direction. Its electric field was, $E_{\text{inc}}$:

$$
E_{\text{inc}} = jE_0 \cdot e^{-j\kappa_{w}z},
$$

where $\kappa_w$ is the wave number in medium. The dielectric function of water was modelled using Drude formalism, to account for a presents of free electron plasma as:

$$
\varepsilon_w = \varepsilon_{\infty} - \frac{ne^2}{\varepsilon_0 m (\omega^2 + j\omega/\tau)},
$$

where $\varepsilon_{\infty}$ is the water relative permittivity (assuming biologically relative refractive index of 1.4), $m$ is the electron reduced mass and $\tau$ is the mean free time between electron/molecule collisions.

The size-dependent corrections to the complex dielectric function of gold, $\tilde{\varepsilon}$, are based on the recent quantitative comparison of a finite element model of a single gold nanorod against spatial modulation spectroscopy (SMS) technique. The solution to the Helmholtz wave equation provides the optical behaviour of a gold nanoparticle, such as electric field enhancement, $|E|/E_0$ and absorption cross-section, $\sigma_{\text{abs}}$. The combination of perfect matched layer (PML) domain and absorbing boundary condition was used to truncate electromagnetic simulations domain and reduce reflections from artificial boundaries. The perfect electric (PEC) and perfect magnetic (PMC) conductor boundaries were used to truncate domain to one quarter of full 3D geometry.
Two temperature model

The resistive losses during laser pulse interaction with gold nanoparticle, $Q_{rh}$, calculated from the electromagnetic model is fed into a hyperbolic two-temperature model (TTM)\textsuperscript{S2} to solve for the energy transfer between the laser pulse and the conduction electrons of gold due to electron-phonon relaxation and heat diffusion from the gold lattice to the surrounding medium through interface conductance, $Q_{au|w}$.\textsuperscript{S3}

\begin{equation}
C_e \frac{\partial T_e}{\partial t} + \nabla \cdot \mathbf{q}_e = -G(T_e - T_l) + Q_{rh} \cdot f(\tau_w),
\end{equation}
\begin{equation}
\tau_e \frac{\partial \mathbf{q}_e}{\partial t} + \mathbf{q}_e = -\kappa_e \nabla T_e
\end{equation}
\begin{equation}
C_l \frac{\partial T_l}{\partial t} + \nabla \cdot \mathbf{q}_l = G(T_e - T_l),
\end{equation}
\begin{equation}
\tau_l \frac{\partial \mathbf{q}_l}{\partial t} + \mathbf{q}_l = -\kappa_l \nabla T_l,
\end{equation}
\begin{equation}
Q_{au|w} = q_0(T_1 - T_m).
\end{equation}

Plasma formation

The temperature rise of the conduction electrons in gold from the TTM and the electric field distribution from the electromagnetic model are used as input parameters to the plasma model. The interaction of the strong electromagnetic fields with the electrons in a aqueous medium can lead to multiphoton, impact and avalanche ionization of the electrons into a quasi-free state in the conduction band. When the density of the excited electrons reaches a critical value of $10^{18} - 10^{20}$ cm$^{-3}$,\textsuperscript{S4,S5} the electron cloud starts to gain sufficient kinetic energy from the interaction with the laser pulse that an optical breakdown occurs. Laser-induced
breakdown can lead to the breakage of atomic bounds, bubble formation, luminescence and acoustic shock formation. In order to determine threshold of plasma induced optical breakdown in aqueous media, the medium can be represented as water with properties of an amorphous semiconductor with a band gap energy of $E_{\text{gap}} = 6.5$ eV. To model the changes in free electron density and determine the irradiance threshold for optical breakdown, the generic form of the rate equation for free electron density, $\rho_e$, can be used:

$$\frac{d\rho_e}{dt} = \left( \frac{d\rho_e}{dt} \right)_{\text{photo}} + \left( \frac{d\rho_e}{dt} \right)_{\text{casc}} + \left( \frac{d\rho_e}{dt} \right)_{\text{diff}} + \left( \frac{d\rho_e}{dt} \right)_{\text{rec}} \quad (10)$$

The $\left( \frac{d\rho_e}{dt} \right)_{\text{photo}}$ term on the right-hand side of Equation (10), models photoionization of electrons via multiphoton absorption and tunnel ionization. The $\left( \frac{d\rho_e}{dt} \right)_{\text{casc}}$ term adds the contribution of cascade ionization (sometimes called avalanche ionization) via inverse Bremsstrahlung absorption. The $\left( \frac{d\rho_e}{dt} \right)_{\text{diff}}$ and $\left( \frac{d\rho_e}{dt} \right)_{\text{rec}}$ terms represent free electron plasma diffusion and recombination, respectively.

To complete the picture of the free electron plasma formation by laser pulse interactions with a gold nanoparticle, two additional processes needs to be considered: thermal ionization (thermionic emission), $\rho_{\text{therm}}$, and photo-thermal emission, $\rho_{\text{au}}$.

The thermal ionization starts to play a significant role in free electron production when the temperature in the focal volume of the laser is sufficiently high ($\approx 5000$ K and above) and large free electron densities are already achieved by multiphoton and cascade ionization. On the other hand, thermal ionization also plays a role during sequences of ultrashort laser pulses, when the time delay between pulses is in the order of thermalization time of the electron plasma energy. Thermal ionization also partially depletes the density of bound electrons in the valence band and reduces the rate of multiphoton and impact ionization.

Although in the model, the temperature of the medium during single pulse illumination is sufficiently lower than 5000 K, we incorporated thermal ionization therm, based on derivations given by Linz et al. into free electron density rate Equation (10) to have complete picture of the free electron plasma generation, so that it can be used for future studies of...
ultrashort pulses of a high repetition rates. Please note that in present single 6 ps pulse study thermal ionization of the water is negligible and can be omitted.

Photo-thermal emission of hot electrons on the boundary of the gold, also starts to play a role when the temperature of the nanoparticle’s electrons rises to a level where the electrons can cross the metal/medium energetic barrier of $W_{au} = 3.72$ eV and contribute to electron density plasma formation.

4 terms in the generic rate Equation [10], plus thermal ionization of water, $\rho_{therm}$, and photo-thermal emitted electron current density across gold/water boundary, of low density plasma formation are expanded as follows:

**The photoionization rate**, $\frac{d\rho_e}{dt}_{\text{photo}}$:

$$
\frac{d\rho_e}{dt}_{\text{photo}} = \frac{2\omega}{9\pi} \left( \frac{m\omega}{\hbar \gamma} \right)^{3/2} Q \left( \frac{\Delta}{\hbar \omega} \right) \frac{\rho_{bound} - \rho_e + \rho_{au}}{\rho_{bound}} \exp \left\{ -\pi \left( -\frac{\Delta}{\hbar \omega} + 1 \right) \times \left[ K \left( \frac{\gamma}{\sqrt{1 + \gamma^2}} \right) - E \left( \frac{\gamma}{\sqrt{1 + \gamma^2}} \right) \right] / E \left( \frac{1}{\sqrt{1 + \gamma^2}} \right) \right\};
$$

$$
Q(\gamma, x) = \sqrt{\frac{\pi}{2K \left( \frac{1}{\sqrt{1 + \gamma^2}} \right)}} \times \sum_{l=0}^{\infty} \exp \left\{ -\pi l \times \left[ K \left( \frac{\gamma}{\sqrt{1 + \gamma^2}} \right) - E \left( \frac{\gamma}{\sqrt{1 + \gamma^2}} \right) \right] / E \left( \frac{1}{\sqrt{1 + \gamma^2}} \right) \right\}
\times \Phi \left\{ \left[ \pi^2 (2 \langle x + 1 \rangle - 2x + l) \right] / 2K \left( \frac{1}{\sqrt{1 + \gamma^2}} \right) \times E \left( \frac{1}{\sqrt{1 + \gamma^2}} \right) \right\}^{1/2},
$$

where $\gamma$ is the Keldysh parameter given by:

$$
\gamma = \frac{\omega}{\omega_t} = \frac{\omega \sqrt{mE_{gap}}}{eE} = \frac{\omega}{e} \sqrt{\frac{\epsilon_0 m E_{gap} n}{2I_{tot}(t)}};
$$

here, $1/\omega_t$, is the tunnelling time through the atomic potential barrier, $m$ is the electron reduced mass, and $\tilde{\Delta}$ is the effective ionization potential for creating an electron-hole pair.
in a condensed matter exhibiting a band structure and corrected for the oscillation energy of the electron due to the electromagnetic field. It is given by:

\[
\tilde{\Delta} = \frac{2}{\pi} E_{\text{gap}} \frac{\sqrt{1 + \gamma^2}}{\gamma} \mathcal{E} \left( \frac{1}{\sqrt{1 + \gamma^2}} \right).
\] (13)

In Equation (11), \(< x >\) represents the integer part of the number \(x\), \(K()\) and \(\mathcal{E}()\) denote the elliptic integrals of the first and second kind, and \(\Phi()\) denotes the Dawson probability integral:

\[
\Phi(z) = \int_0^z \exp(y^2 - z^2)dy.
\] (14)

**The cascade ionization rate,**

Cascade ionization contributes to the rate Equation (10) only after certain initial free electron density, \(\rho_{\text{seed}}\), has been reached by either photoionization or photo-thermal emission. The initial seed free electron density is the fitting parameter and is chosen based on 50 % probability of having at least one seed electron in the focal volume of laser.\(^{20}\) Then cascade ionization rate can be written as:

\[
\left( \frac{d\rho_e}{dt} \right)_{\text{casc}} = \begin{cases} 
\alpha_{\text{casc}} I_{\text{inc}}(t) \times \rho_e & \text{for } \rho_e \geq \rho_{\text{seed}} \\
\frac{\alpha_{\text{casc}}}{1 + \eta_{\text{casc}}I_{\text{ret}}} \times (\rho_e - \rho_{\text{therm}}) \times (\rho_e - \rho_{\text{therm}}) & \text{for } \rho_e < \rho_{\text{seed}} 
\end{cases}
\] (15)

**Thermal ionization,**\(^{20}\)

Based on derivation of Linz *et al.*,\(^{20}\) the third process of free electron generation can come from thermalization of energy, carried by primary free electrons via thermal emission. Thermally ionized free electron density in the conduction band is calculated by:
\[
\left( \frac{\partial \rho_{\text{therm}}}{\partial t} \right) = \frac{\partial T_w}{\partial t} \left( \frac{3\kappa_b}{E_{\text{gap}}} + \frac{1}{T_w} \right) \frac{3}{2} \sqrt{\frac{\pi}{2}} \left( \frac{\kappa_b T_w}{E_{\text{gap}}} \right)^{\frac{3}{2}} \exp \left( -\frac{E_{\text{gap}}}{2\kappa_b T_w} \right) \left( \rho_{\text{bound}} - \rho_e \right) \quad (16)
\]

**Photo-thermal emission current, \( J_{\text{au}} \)**

The photo-thermal emitted electron current density across metal/medium boundary can be described by generalized Fowler-DuBridge theory of multiphoton photoemission at high temperatures:

\[
J_{\text{au}} = A_0 T_e^2 \exp \left( -\frac{eW_{\text{au}}}{\kappa_b T_e} \right) + c_{\text{au}} \frac{2(\kappa_b T_e)^2}{4(3h\omega - W_{\text{au}})^2} F \left( \frac{3h\omega - W_{\text{au}}}{\kappa_b T_e} \right) (1 - R)^3 I_{\text{tot}}^n(t) n \quad (17)
\]

where \( A_0 \) is the Richardson coefficient \((120 \, \text{A/cm}^2/\text{K}^2)\), \( W_{\text{au}} \) is work function \((3.72 \, \text{eV})\), \( F \) is the so called Fowler function, \( c_{\text{au}} \) is the three-photon ionization cross-section \((1 \times 10^{-7} \, \text{Acm}^4/\text{MW}^3)\), \( \kappa_b \) is the Boltzmann constant and \( R \) is the reflection coefficient of the gold. The photo-thermal electron current density is set as a boundary flux/source condition across gold/water interface.

The details for diffusion, \( \left( \frac{d\rho_e}{dt} \right)_{\text{diff}} \), and electron-hole recombination rates, \( (\eta_{\text{rec}}) \) of the Equation (10) are given in the Table S1. The first one is based on the characteristic diffusion length, \( \Lambda \), which is set to the radius of the gold nanoparticle. The electron-hole recombination rate is set to empirical value obtained by Docchio.

By implementing above mentioned terms into generic rate Equation (10), plus introducing photo-thermal emission current as a boundary condition, leads to a full description of free electron plasma formation in the vicinity of gold nanoparticle in the form:

\[
\frac{d\rho_e}{dt} = \left( \frac{d\rho_e}{dt} \right)_{\text{photo}} + \left( \frac{d\rho_e}{dt} \right)_{\text{casc}} + \left( \frac{d\rho_e}{dt} \right)_{\text{diff}} + \left( \frac{d\rho_e}{dt} \right)_{\text{rec}} + \left( \frac{d\rho_{\text{therm}}}{dt} \right) \quad (18)
\]

The transient changes in the optical behaviour of the s25t@640 nanoparticle with a fluence of 0.37 mJ/cm² are shown in Figure S1. The dark red line in Figure S1 represents the tempo-
ral evolution of maximum electric field enhancement in the middle of 4 nm gap between two adjacent nanospheres. As the density of free electron plasma, $\rho_e$, reaches $1 \times 10^{19}$ cm$^{-3}$ the plasma becomes highly absorbent to incident laser irradiation and shields the gold nanoparticle. The maximum field enhancement reaches its minimum at the maximum density of the plasma (dip in the near-field enhancement, Figure S1). The 4 ps difference between peak of the laser intensity and the peak of the free electron density is caused by a domination of photo-thermal emission of hot electrons off the nanoparticle’s surface, where photo-thermal emission is proportional to $T_e^2 I_{tot}$.

Figure S1: Temporal evaluation free electron plasma, $\rho_e$ (cm$^{-3}$), shown by the green line; and maximum electric field enhancement, $|E|_{\text{max}}/E_0$, shown by the dark red line for 25 nm nanosphere trimer (s25t@640) irradiated at the resonance peak wavelength, 640 nm, with the fluence of 0.37 mJ/cm$^3$. The probe point located at the middle of the edge-to-edge gap between two adjacent nanoparticles. The grey shaded area shows the laser intensity profile (in arbitrary units). The time is normalized to FWHM of the laser pulse, $\tau_w$. 

S8
Heat transfer in aqueous media

The temperature increase in the aqueous media, $T_w$, due to the laser-particle interaction, linear absorption (Joule heating), plasma formation and optical breakdown, is modelled by solving heat transfer equation. There were four types of heat sources: 1) a Dirichlet boundary condition of the interface conductance at the nanoparticle surface - Equation (9); 2) Joule heating with the plasma produced in the vicinity of the nanoparticle, $Q_{rh}$; 3) electron collision losses with neutral molecules during impact ionization, $(\frac{dT_m}{dt})_{coll}$; 4) heating through electron recombination of ionized molecules, $(\frac{dT_m}{dt})_{rec}$. With above mentioned considerations, the heat transfer equation will following:

$$\rho_w c_w \frac{\partial T_w}{\partial t} = \nabla (\kappa_w \nabla T_w) + Q,$$

where heat source, $Q$, is:

$$Q = Q_{rh} \cdot f(\tau_w) + \left(\frac{dT_m}{dt}\right)_{coll} + \left(\frac{dT_m}{dt}\right)_{rec}.$$

Table S1: Symbols and constants used in the theory

| Symbol | Value/Expression | Description |
|--------|------------------|-------------|
| $\lambda$ | Laser wavelength | 299792458 m/s |
| $c_0$ | Speed of light in vacuum | 299792458 m/s |
| $\omega$ | Angular frequency | $\frac{2\pi c_0}{\lambda}$ |
| $\varepsilon_0$ | Vacuum permittivity | 8.854 187 817... × 10^{-12} F/m |
| $\varepsilon$ | Size-dependant dielectric constant | eq. 2 |
| $E$ | Electric field strength | eq. 1 |
| $E_0$ | Incident electric field | $\sqrt{\frac{2I_{inc}}{\varepsilon_0 n_0}}$ |
| $f(\tau_w)$ | Gaussian shape pulse function | $\frac{2.35482}{\tau_w \sqrt{2\pi}} \frac{1}{e^{2(2.35482)^2}}$ |
| $\tau_w$ | Laser pulse width [full width at half maximum (FWHM)] | 6 ps |
| $I_{inc}$ | Incident irradiance of laser light | $\frac{e n_0 I_{inc} c_0}{2}$ |
| $e$ | Electron charge | 1.602176565(35) × 10^{19} C |

Continued on next page
| Symbol | Value/Expression | Description |
|--------|------------------|-------------|
| \(\rho_e\) | see eq. 10 | Density of free electron plasma |
| \(m_e\) | 9.10938291(40) \times 10^{31} \text{ kg} | Electron mass |
| \(\tilde{\varepsilon}_{\text{bulk}}\) | see Johnson and Christy $^{299}$ | Bulk dielectric function |
| \(\mu_0\) | \(4\pi \times 10^7 \text{ N} / \text{ A}^2\) | Magnetic permeability in vacuum |
| \(\omega_p\) | \(\sqrt{\frac{\rho_e e^2}{\varepsilon_0 m_e}}\) | Plasma frequency of free electron gas |
| \(\gamma_0\) | 1.094 \times 10^{14} \text{ 1/s} | Bulk relaxation frequency $^{299}$ |
| \(v_F\) | 1.41 \text{ nm/fs} | Fermi velocity $^{30}$ |
| \(L_{\text{eff}}\) | \(\frac{4V_{\text{au}}}{\pi a_{\text{au}}}\) | Reduced effective mean free path length $^{31}$ |
| \(V_{\text{au}}\) | | Volume of the particle |
| \(S_{\text{au}}\) | | Surface area of the particle |
| \(\eta\) | \((5.5 \pm 1.5) \times 10^{-7} \text{ fs}^{-1} \text{ nm}^{-3}\) | Radiation damping proportionality constant $^{32}$ |
| \(A\) | 0.5 | Broadening parameter $^{31}$ |
| \(\sigma_{\text{abs}}\) | \(\frac{1}{V_{\text{inc}}} \int_{V_{\text{au}}} \Re(Q_{\text{rh}})dV_{\text{au}}\) | Absorption cross-section of the gold nanoparticle $^{33}$ |
| \(\Re\) | | Real part |
| \(n\) | 1.40 | Refractive index of water $^{34}$ |
| \(D\) | | Dielectric displacement |
| \(\sigma\) | | Electric conductivity |
| \(\Im\) | | Imaginary part |
| \(Q_{\text{rh}}\) | \(\frac{1}{2} \Re[(\sigma - j\omega\varepsilon)\mathbf{E} \cdot \mathbf{E}^*]\) | Resistive losses during laser pulse interaction $^{33}$ |
| \(C_e\) | see ref $^{33}$ | Electronic heat capacity of gold |
| \(C_l\) | see ref $^{33}$ | Lattice heat capacity of gold |
| \(T_e\) | see eq. 5 | Electronic temperature of gold |
| \(T_l\) | see eq. 7 | Lattice temperature of gold |
| \(q_e\) | see eq. 6 | Electronic heat flux vector (TTM model) |
| \(q_l\) | see eq. 8 | Lattice heat flux vector (TTM model) |
| \(G\) | \(2 \times 10^{16} \text{ W m}^{-3} \text{ K}^{-1}\) | Electron-phonon coupling factor $^{33}$ |
| \(\tau_e\) | \((1.2 \times 10^7 * T_e^2 + 1.23 \times 10^{11} * T_l)^{-1} \text{ s}\) | Electron collision time $^{32}$ |
| \(\tau_l\) | 0.8 ps | Ion collision time $^{35}$ |
| \(\kappa_e\) | see ref $^{35}$ | Electron thermal conductivity |
| \(\kappa_l\) | see ref $^{32}$ | Lattice thermal conductivity |
| Symbol | Value/Expression | Description |
|--------|-----------------|-------------|
| $\rho_{\text{bound}}$ | $6.68 \times 10^{22}$ e/cm$^3$ | Bound electron density of water\[S36\] |
| $I_{\text{tot}}$ | $\frac{c_0 m_e E^2}{2} f(\tau_w)$ | Irradiance of laser pulse |
| $\eta_{\text{casc}}$ | $\frac{1}{\omega^2 \tau^2 + 1} \int \frac{e^2 \tau}{c_0 m_e c_m c_w (3/2) \Delta} I_{\text{tot}}(t) - \frac{m_e \omega^2 \tau}{M}$ | Cascade ionization rate\[S38\] |
| $\bar{\Delta}$ | see eq. 13 | Effective ionization potential |
| $\gamma$ | see eq. 12 | Keldysh parameter\[S14\,S20\] |
| $M$ | $3 \times 10^{-26}$ kg | Mass of water molecule |
| $\tau$ | 1.6 fs | Mean free time between electron/molecule collisions\[S20\] |
| $t_{\text{ret}}$ | $\tau \left(1 + \frac{2\bar{\Delta}}{\omega \tau}\right)$ | Cascade retardation time\[S20\] |
| $h_i$ | $1.98644568 \times 10^{-25}$ J·m | Reduced Planck constant |
| $E_{\text{gap}}$ | 6.5 eV | Band gap energy of water\[S7\,S12\] |
| $\alpha_{\text{casc}}$ | $\frac{1}{\omega^2 \tau^2 + 1} \frac{2 e^2 \tau}{c_0 m_e E_{\text{gap}}} \left(1 - \frac{\rho_e + \rho_{\text{au}}}{\rho_{\text{bound}}}\right)$ | Gain in cascade ionization\[S20\] |
| $\beta_{\text{casc}}$ | $\frac{m_e \omega^2 \tau}{M} \frac{\omega^2 \tau}{\omega^2 \tau + 1} \left(1 - \frac{\rho_e + \rho_{\text{au}}}{\rho_{\text{bound}}}\right)$ | Collision loss term of cascade ionization\[S20\] |
| $\left(\frac{d\rho_e}{dt}\right)_{\text{diff}}$ | $-\eta_{\text{rec}} \cdot (\rho_e - \rho_{\text{therm}})^2$ | Characteristic diffusion length\[S27\] |
| $\Lambda$ | set as a radius of gold nanoparticle | Empirical recombination rate\[S25\] |
| $\eta_{\text{rec}}$ | $2 \times 10^{-9}$ cm$^3$/s | Recombination of free electron plasma |
| $\left(\frac{d\rho_e}{dt}\right)_{\text{rec}}$ | | Heating through collision losses during impact ionization\[S20\] |
| $\left(\frac{dT_m}{dt}\right)_{\text{coll}}$ | $\frac{5}{4} c_w \rho_w E_{\text{gap}} \beta_{\text{casc}} (\rho_e - \rho_{\text{therm}})$ | Heating through recombination\[S20\] |
| $\left(\frac{dT_m}{dt}\right)_{\text{rec}}$ | $\frac{5}{4} c_w \rho_w E_{\text{gap}} \eta_{\text{rec}} (\rho_e - \rho_{\text{therm}})^2$ | Density of thermally ionized electrons in the medium\[S20\,S21\] |
| $\rho_{\text{au}}$ | see eq. 18 | Density of electrons emitted off the gold surface\[S25\] |
| $\rho_{\text{therm}}$ | see eq. 17 | Heat capacity of water |
| $c_w$ | 4184 J/kg/K | Density of water |
| $\rho_w$ | 1000 kg/m$^3$ | Thermal conductivity of water |
| $\kappa_w$ | 0.61 W/m/K | Temperature of water |
| $T_w$ | see eq. 19 | Thermal conductance at gold-water interface\[S37\] |
| $q_0$ | $105.0 \times 10^6$ W/m$^2$/K | |
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