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# Thermal memory based photoacoustic imaging of temperature: supplementary material

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**The impact of the laser burst on the photoacoustic signal amplitude**

As we have discussed in the Methods, assuming the number of laser pulses is *N* and the pulse-to-pulse time interval is $t_p$, and $\tau_{th}$ is much longer than the total burst duration $N \cdot t_p$, we can approximate that the thermal energy converted from the absorbed optical energy is confined within the resolution voxel. Then, the temperature rise induced by the laser burst at the time when the Nth laser pulse strikes can be calculated as

$$\Delta T = \frac{(N-1)\eta\mu_a\Phi\delta t}{\rho C_V}, \quad \text{(S1)}$$

where $\rho$ is the mass density of the tissue (1 g/cm$^3$ for muscle). $C_V$ is the specific heat capacity at constant volume (3.8 J/g/K for muscle). Note that this approximation is only valid when the bust duration is much shorter than the thermal relaxation time so that the heat dissipation due to thermal diffusion is negligible.
Then, the increase in the Grüneisen parameter is

$$\Delta\Gamma = k_T \Delta T = \frac{k_T (N-1)\eta\mu_a\Phi\delta t}{\rho C_V}, \quad \text{(S2)}$$

where $k_T$ is the linear dependence of the Grüneisen parameter on the temperature (0.0086 for muscle).
Therefore, the PA signal amplitude excited by the Nth laser pulse can be expressed as

$$p_N = (\Gamma_0 + \Delta\Gamma)\eta\mu_a\Phi\delta_t. \quad \text{(S3)}$$

Substituting Eq. (S2) into Eq. (S3), we have

$$p_N = \left(\Gamma_0 + \frac{k_T (N-1)\eta\mu_a\Phi\delta t}{\rho C_V}\right)\eta\mu_a\Phi\delta_t, \quad \text{(S4)}$$
$$= \left(\Gamma_0 + b(N-1)\eta\mu_a\Phi\delta t\right)\eta\mu_a\Phi\delta_t$$

where $b = k_t / (\rho C_V)$, the first-order derivative of the Grüneisen parameter with respect to the absorbed photon energy, with a unit of cm$^3$/J or Pa$^{-1}$. Thus, we get Eq. (2) in the main text.

**The calibration of the HIFU-induced temperature rise in chicken tissue**

In the HIFU calibration experiment, a piece of fresh chicken breast tissue with a thickness of 1.5 cm was treated by our HIFU transducer. The HIFU transducer (H-102, Sonic Concepts, USA; Focal length: 63 mm) was fixed at the bottom level of the 3D mount. The HIFU transducer was operated at 1.1 MHz (1st harmonic) with a duty cycle of 10%, driven by a function generator and a 55-dB power amplifier (A150, Electronic Navigation Industries, USA). The temperature profile at the HIFU focus was measured by using a 0.1 mm bare-wire thermocouple (Custom designed IT-23, Physitemp Inc, Clifton, NJ) inserted into the chicken tissue. Temperature output voltage was registered in an electronically compensated isothermal terminal block (TC-2190, National Instrument) and subsequently conditioned and sampled at a rate of 60 Hz using a Data Acquisition Board (NI4351, National Instrument) controlled by a LabView program. The thermocouple embedded in the tissue was first aligned to the HIFU focus by operating the HIFU transducer at a low intensity while scanning the tissue across the acoustic field to search for the position of maximum temperature increase. Using this approach, temperature elevations inside the chicken tissue were measured for the designated HIFU exposure conditions. A 5-second HIFU treatment with an average power of 900 Watt/cm$^2$ was applied to elevate the temperature in the HIFU focus inside the chicken tissue, during and after which the temperature measurements were repeatedly performed for a total of 10 seconds, as shown in Fig. S1. The results clearly show the temperature was elevated by about 40 °C during the HIFU heating,

which was roughly consistent with our experimental results in the mouse limb shown in Fig. 5.

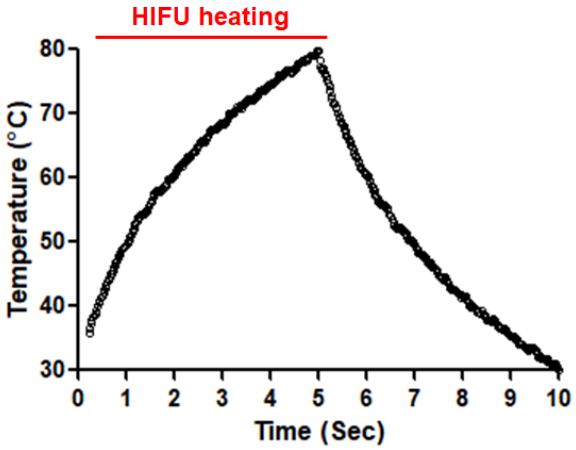


**Fig. S1. The temperature profile at the HIFU focus inside chicken tissue during HIFU heating, measured by a thermocouple.** Note the HIFU-heating time was 5 seconds.