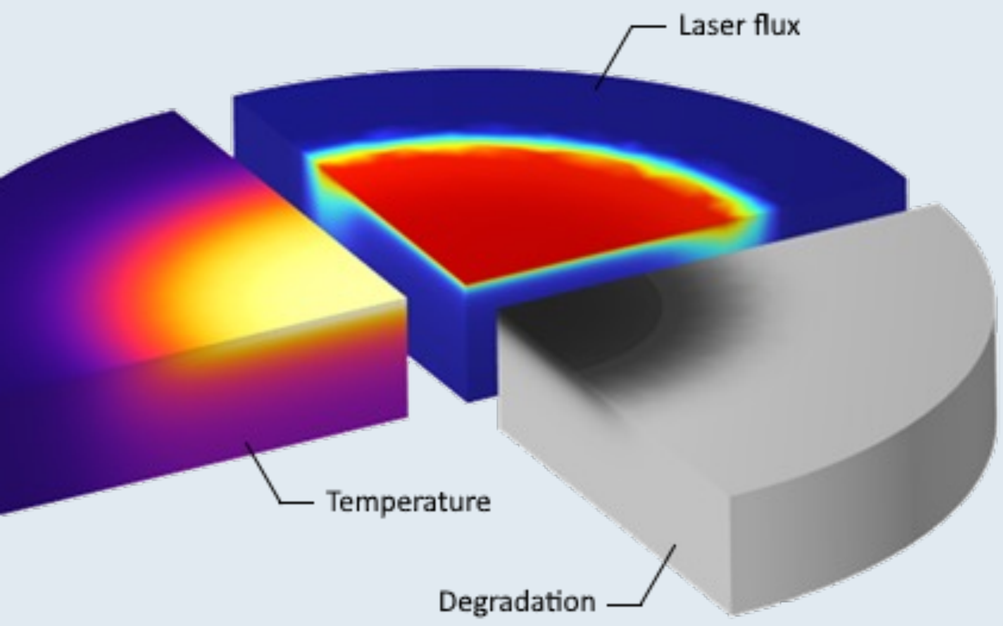

The Dynamic Heating of Translucent Composite Materials Under a High-Energy Laser Irradiation

Modeling the optical propagation of a laser beam within a glass fiber-reinforced polymer, and the subsequent heating of the material up to very high temperatures.

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Goals

Glass fiber-reinforced plastics show a very dynamic behavior when submitted to a laser illumination.

The reinforcement fibers and the polymer matrix both are initially transparent in the near infrared spectrum but present different refractive indexes, leading to the scattering of laser light and to a very complex diffusion of the laser energy within the volume of the composite material.

The absorbed laser energy nevertheless quickly heats up the material and the heat-sensitive polymer turns into an opaque charred residue, dramatically modifying the optical behavior of the system. This higher absorption of the laser light leads to a faster temperature rise until a thermal equilibrium is reached on the illuminated area, while heat diffusion carries on by means of thermal conduction towards the rear face.

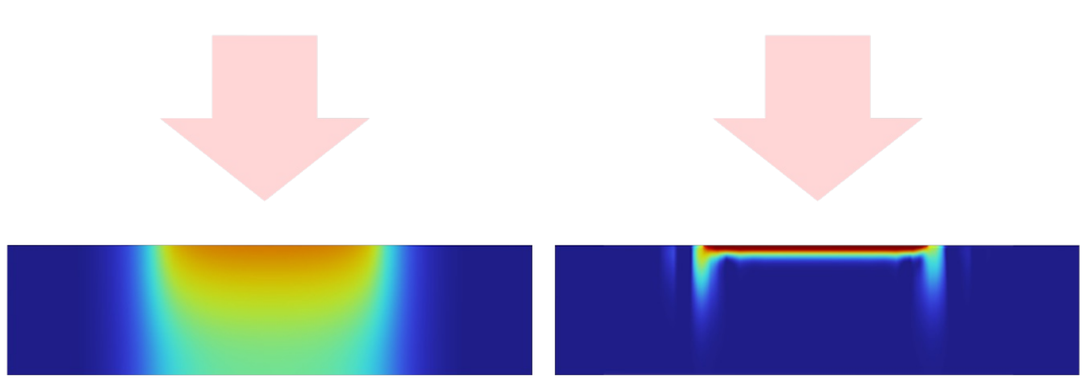

FIGURE 1. Laser light propagation before (left) and after (right) the degradation of the irradiated area.

Methodology

The translucent composite material is modeled in 3D as an equivalent homogeneous body with effective optical and thermal properties.

The heating is driven by the absorption of two different light fluxes: the initially collimated laser light flux (see the Beer's law[1]), and an isotropic diffuse light flux resulting from the scattering of the initial laser beam (see the Photon Diffusion Equation).

With intense laser fluxes involved, the temperature quickly raises and the polymer material turns into a charred residue (see the Arrhenius Equation[2]). This irreversible deterioration towards an absorbing material speeds up the heating process.

Results

Figures 1 and 2 show the numerical outcomes for a laser illumination of 500 W during 10 seconds.

The degradation of the polymer on the front face begins about 2 seconds after the start of the irradiation. Its influence on the laser flux distribution is clearly visible: while the laser light can travel with the volume of the initially translucent material, it is concentrated on the surface when the material becomes opaque.

The temperature evolution also is highly affected by this reaction, with a higher concentration of laser energy after the material turns opaque, and thus a faster temperature rise on the front face until a thermal equilibrium is reached.

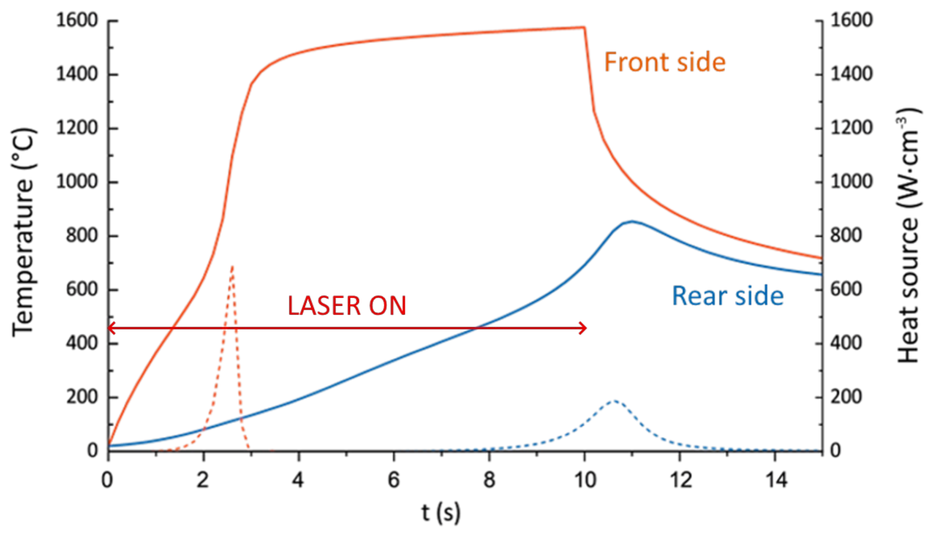

FIGURE 2. Temperature evolution and released energy during the deterioration process.

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