27th International Conference on Magnet Technology (MT27)

Fukuoka, Japan / 2021

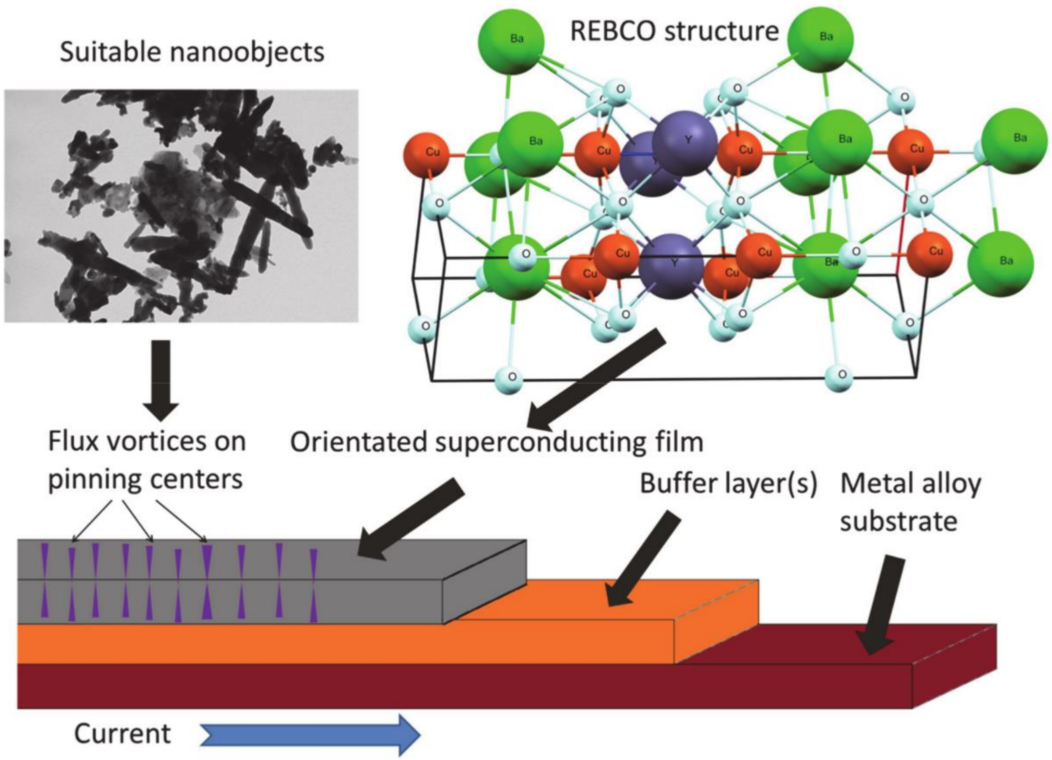
National Research Nuclear University "MEPhI"
Department of the Solid State Physics and Nanosystems

Features of the formation of pinning centers in HTS tapes under the laser irradiation action

I. Anishenko, S. Pokrovskii, D. Abin, M. Osipov, I. Rudnev

mephizic@gmail.com

Simulation



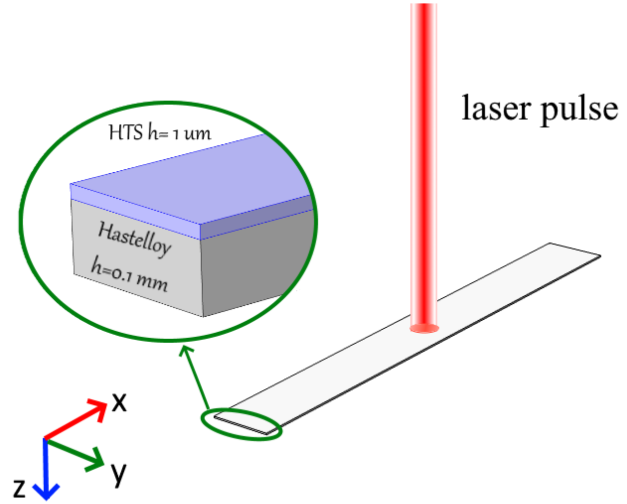
High-temperature superconducting (HTS) tapes stacks GdBa2Cu3O7-x of the second generation

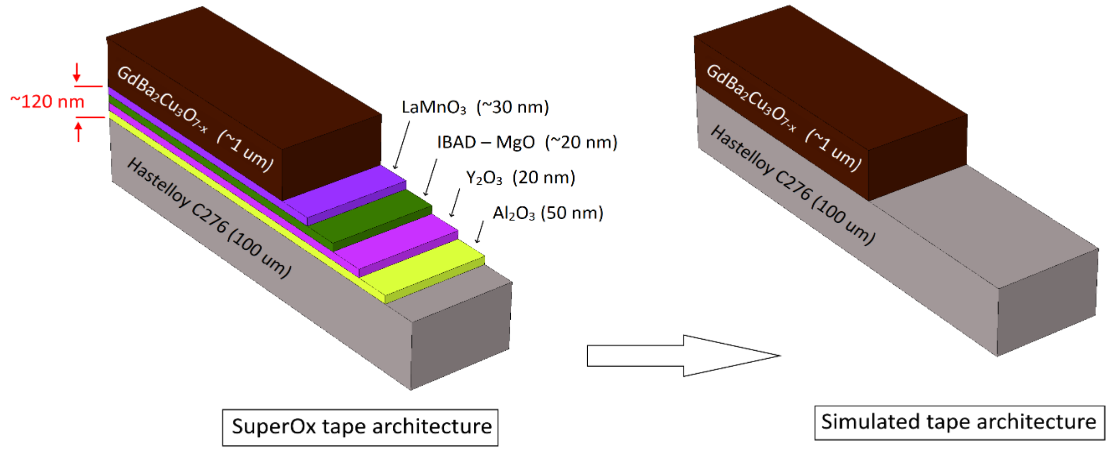
As the main tools for controlled effects on superconductors, leading to a change in their properties were used

- the introduction of nanoscale additives in the solid-phase synthesis of HTS [1],
- surface modification by scratching [2],
- etching [3],
- magnetic islands deposition [4],
- irradiation with high-energy particles (protons [5], neutrons [6], electrons [7]).

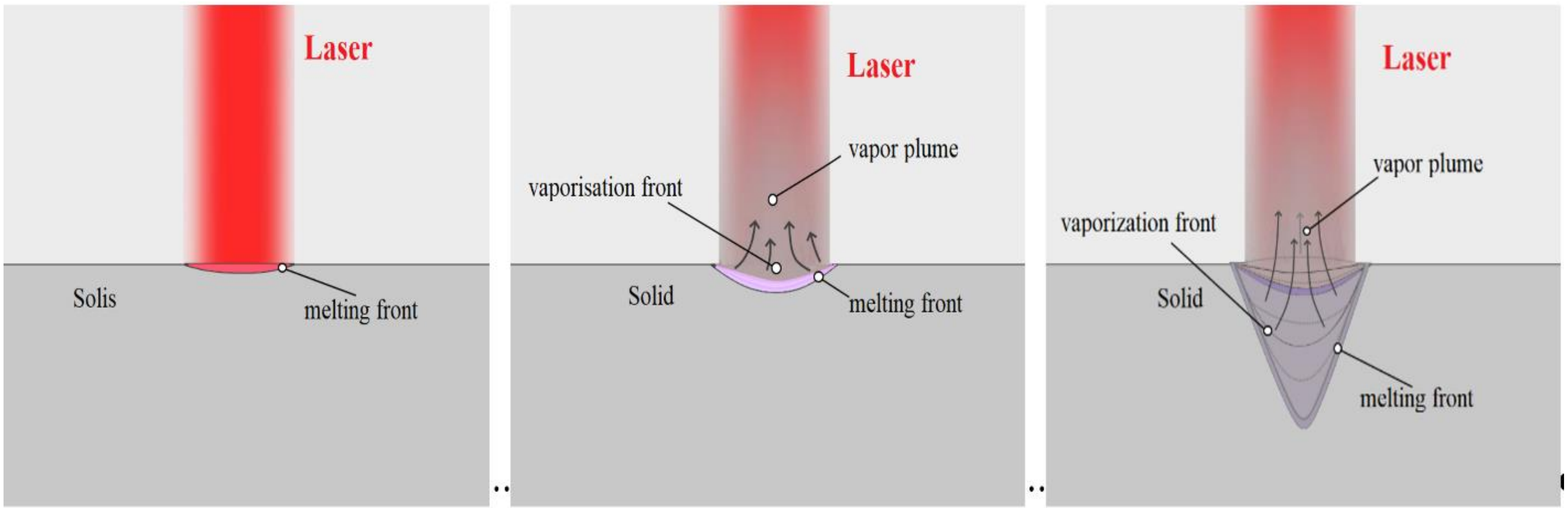
1. Influence of doping of TiC and NbC on structure and superconducting properties of Bi-containing compounds / B. P. Mikhailov, N. F. Tazetdinova, G. M. Leitus et al. // J. Low Temp. Phys. - 1996. — Vol. 105. — P. 1553-1557.
2. Reduction of the microwave surface resistance in YBCO films by microscopic defects / J. Einfeld, P. Lahl, R. Kutzner et al. // Physica C. 2001.- Vol. 351.- P. 103-117.
3. Anisotropic vortex channelling in YBaCuO thin films with ordered antidot arrays / A. Crisan, A. Pross, D. Cole et al. // Phys. Rev. B.— 2005.— Vol. 71. P. 144504-1-144504-10.
4. Magnetic pinning of the vortex lattice by arrays of submicrometric dots / Y. Jaccard, J. I. Martin, M.-C. Cyrille et al. // Phys. Rev. B. 1998. — Vol. 58, № 13. - P. 8232-8235.
5. Defect dependence of the irreversibility line in Bi2Sr2CaCu20s single crystals / L. W. Lombardo, D. B. Mitzi, A. Kapitulnik, A. Leone // Phys. Rev. B. 1992. - Vol. 46, № 9. - P. 5615-5620.
6. Velter-Stefanescu, M. Microwave spectroscopy in YBaCuO superconductors: influence of neutron irradiation on the 123 phase / M. Velter-Stefanescu, A. Totovana, V. Sandu //J. Supercond. 1998. - Vol. 11, № 3. - P. 327-330.
7. Effects of weak point disorder on the vortex matter phase diagram in un-twinned YBa2Cu30j, single crystals / T. Nishizaki, T. Naito, S. Okayasu et al. // Phys. Rev. B. 2000. - Vol. 61, № 5. - P. 3649-3654.

Simulation





Architecture of the investigated HTS tapes and the computational system



Simulation

$$\rho\tilde{C}_p\frac{\partial T}{\partial t}+\rho\tilde{C}_p\boldsymbol{u}\cdot\nabla T=\nabla\cdot(k\nabla T)+\alpha q_L-Q_c$$ *- governing equation*

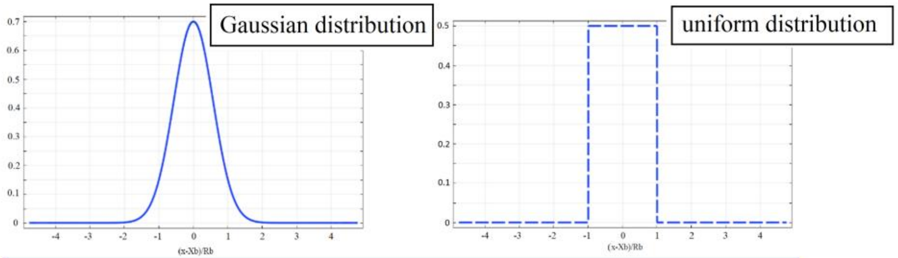
$F=\alpha\cdot q_L$ *- volumetric heat source*

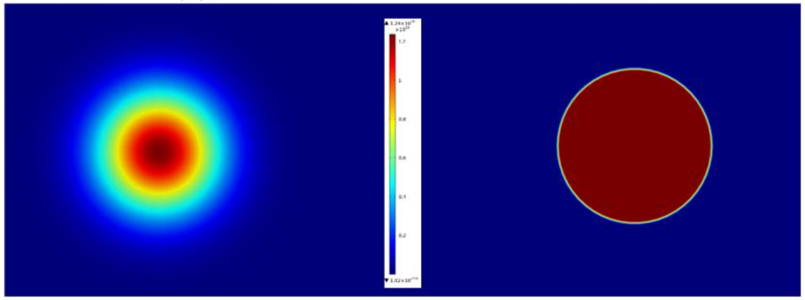
$$q_{L0}(t,x)|_{y=0}=\frac{P_{act}}{R_b}\,g\,(x)\xi(t),\quad g(x)=\,g_u(x)\text{ или }g_n(x),$$

$$g_u(x)=(1/2)H(-|x-\;X_b|+\;R_b)\,,$$

$$g_n(x)=\frac{R_b}{\left(2\pi\sigma_b^2\right)^{1/2}}\exp\left(-\,\frac{(x-X_b)^2}{2\sigma_b^2}\right),$$

$$\xi\;=H(\tau_2-t\bmod\tau_1)\;,$$





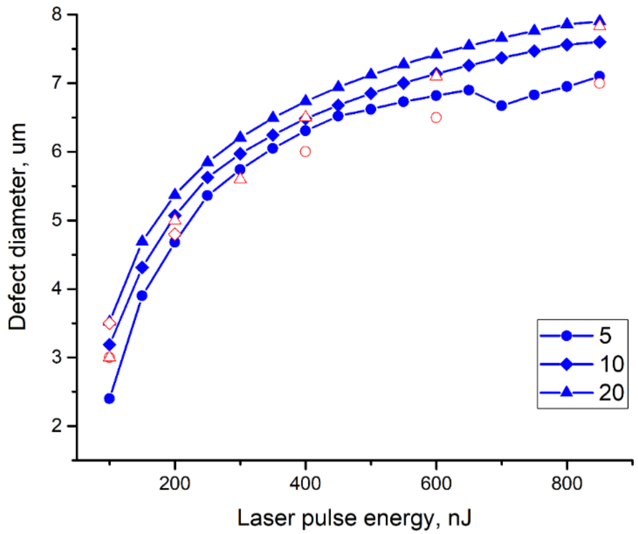
radiation or/and convective cooling:

$$\vec{n}\cdot\vec{q}|_{\partial_1\Omega_{tape}}=\;h_{эфф}\big(T-\;T_{окр}\big)+\epsilon\epsilon_{SB}\big(T^4-\;T_{окр}^4\big)\;,$$

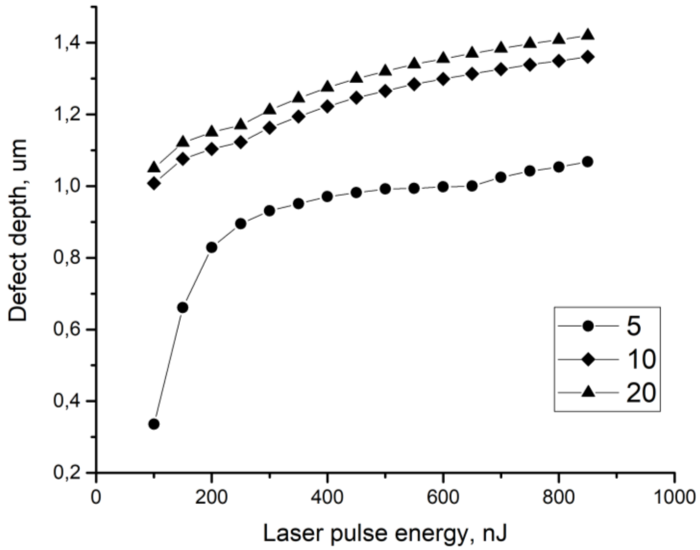
initial conditions: $$T|_{\Omega_{hast},\Omega_{HTS}}=\;T_0$$

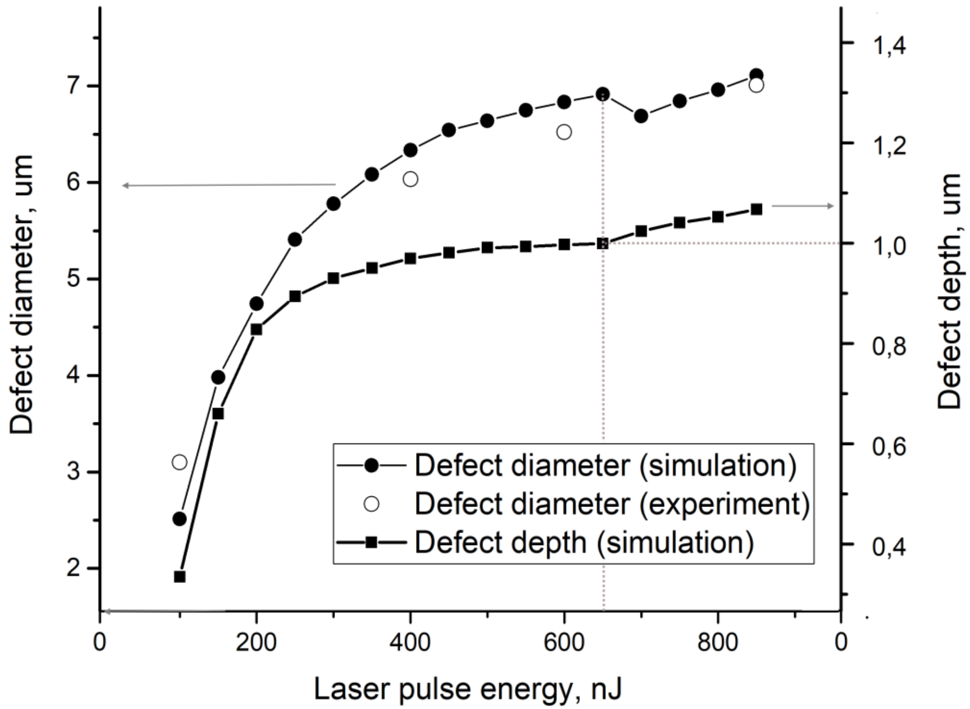
The description of the mechanics of a multiphase fluid is based on the Navier-Stokes, Cahn-Hilliard equations and the continuity equation, implemented in the physical interface of a laminar two-phase flow.

Results: the beam focusing in the 3 μm

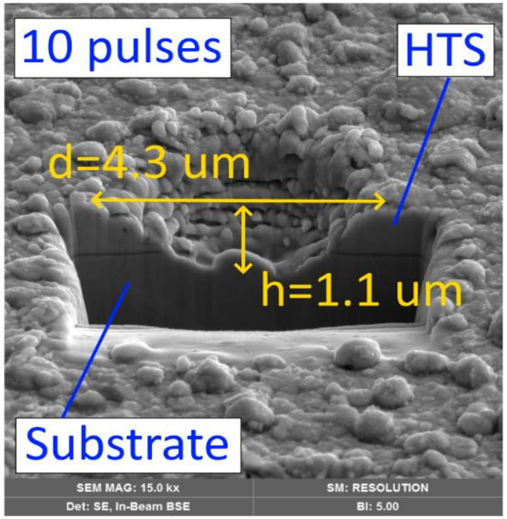


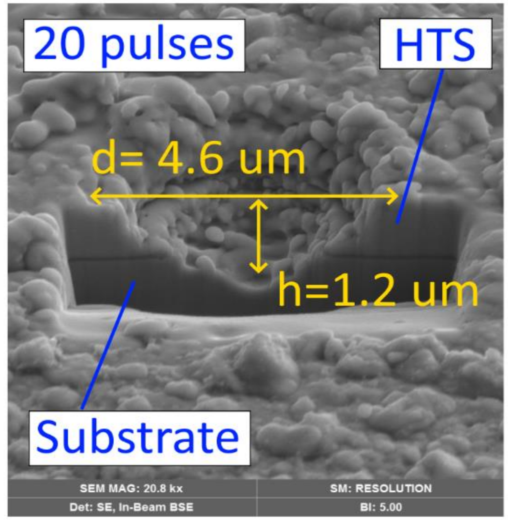
Dependence of the diameter (top) and the depth (bottom) of the defect on the laser energy for a different number of pulses at the one point (the number of pulses is indicated in the legend to the figure). The pulse frequency is 10 Hz, the laser beam focusing radius is 3 μm, and the duration of a single pulse is 2 ps. Closing symbols - calculated values of defect diameters, open symbols - experimental values of defect diameters





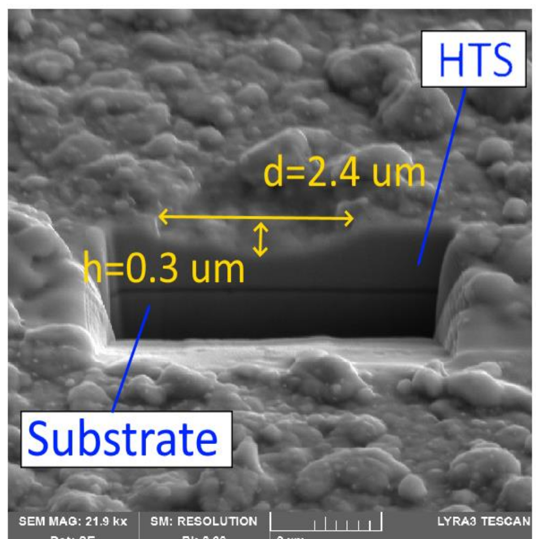
Results: the beam focusing in the 3 µm

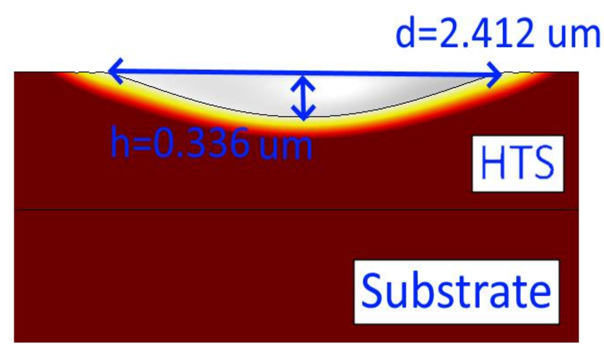




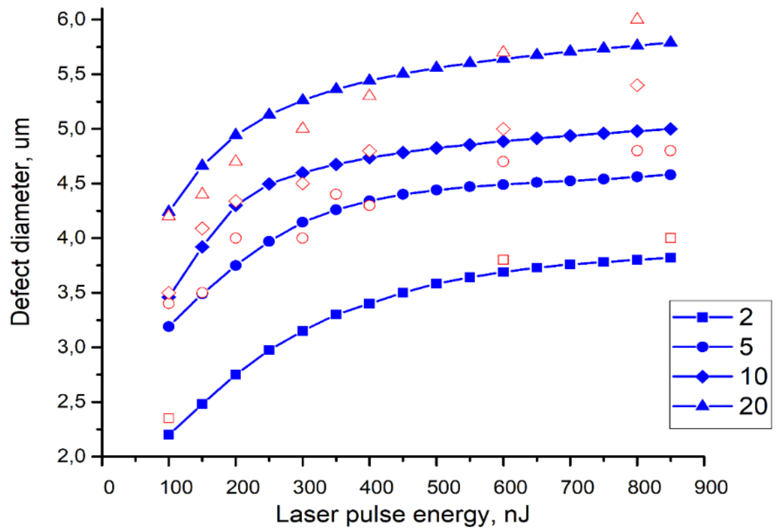
Electronic photographs of samples irradiated with a sequence of 10 and 20 pulses per point. The energy of laser radiation is 150 nJ, the pulse frequency is 10 Hz, and the time of a single pulse is 2 ps.

Experimental and calculated patterns of defects. Radiation energy 100 nJ, 5 pulses per point, frequency 10 Hz, focusing radius 3 µm

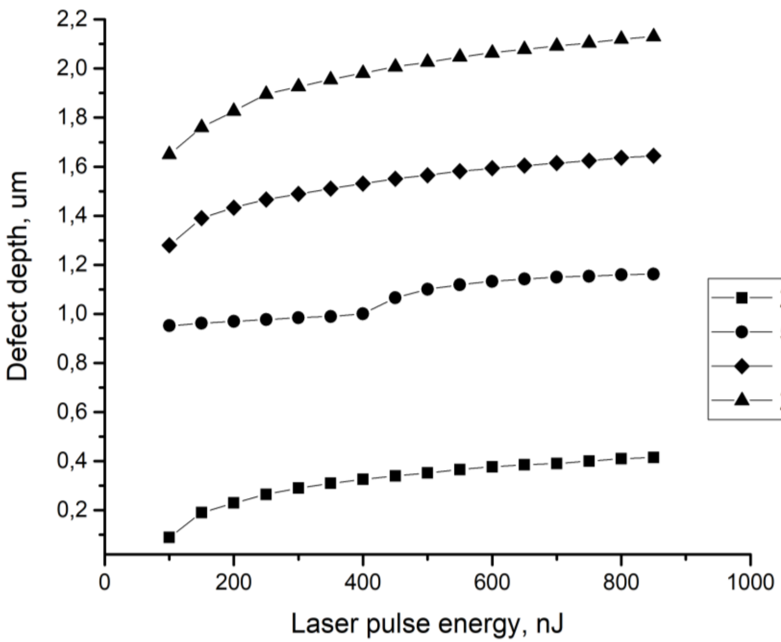


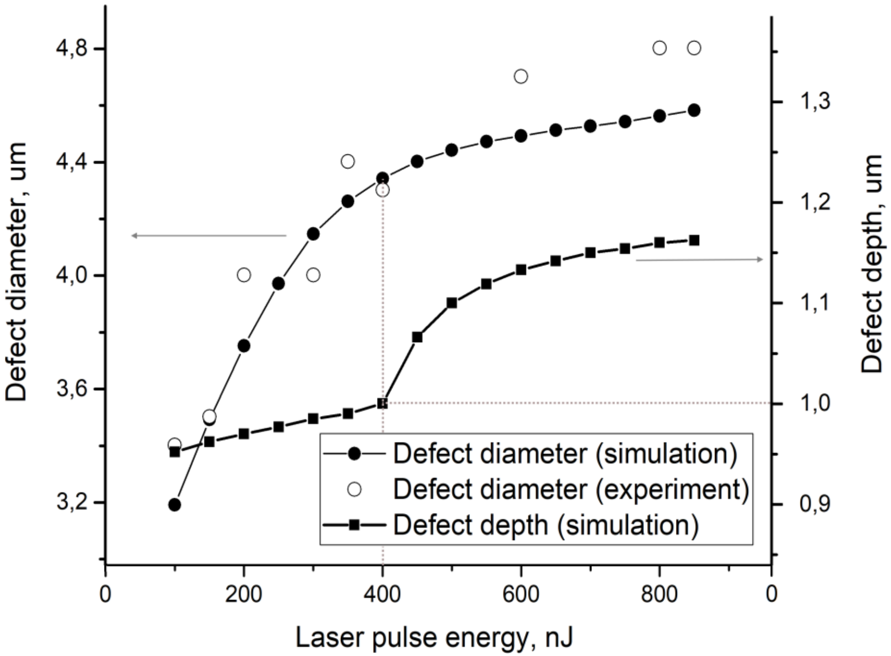


Results: the beam focusing in the 1.5 µm

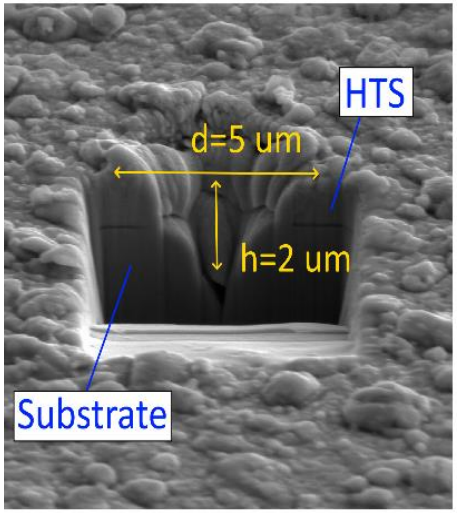


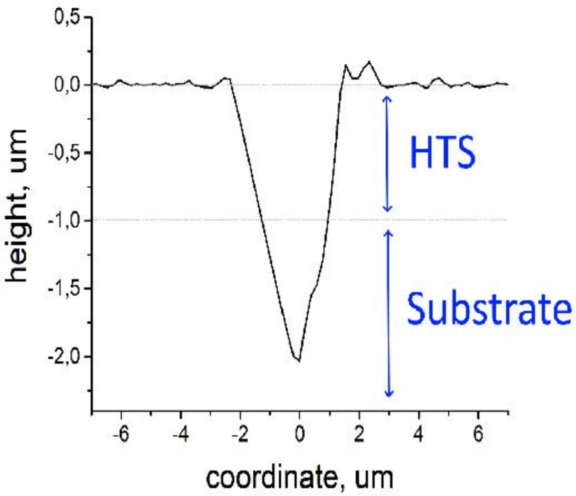
Dependence of the diameter (top) of the defect and the depth (bottom) of the defect on the laser radiation energy for a different number of pulses at one point. The pulse frequency rate is 10 Hz, the focusing radius of the laser beam is 1.5 µm, and the duration of a single pulse is 2 ps. Closing symbols - calculated values of defect diameters, open symbols - experimental values of defect diameters

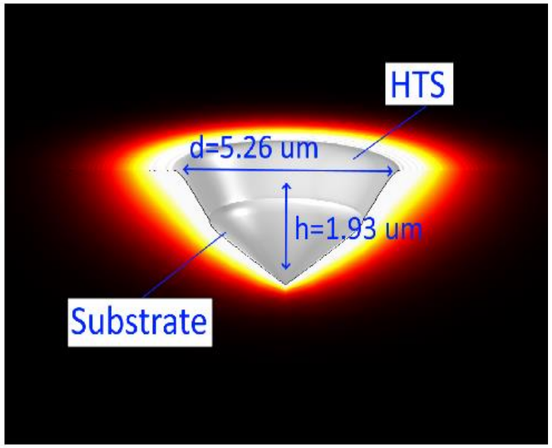




Results: the beam focusing in the 1.5 µm

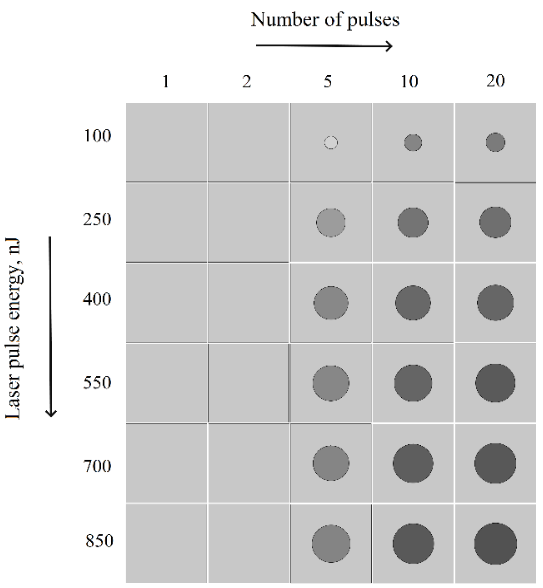




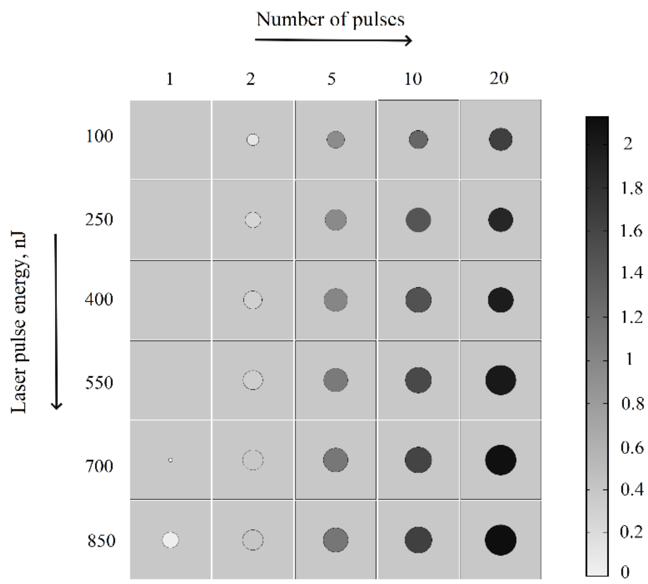


Photograph of a sample, surface relief, calculated image of a composite defect upon irradiation with a sequence of 20 pulses with an energy of 300 nJ, a frequency of 10 Hz. The time of a single pulse is 2 ps, the focusing radius is 1.5 mm.

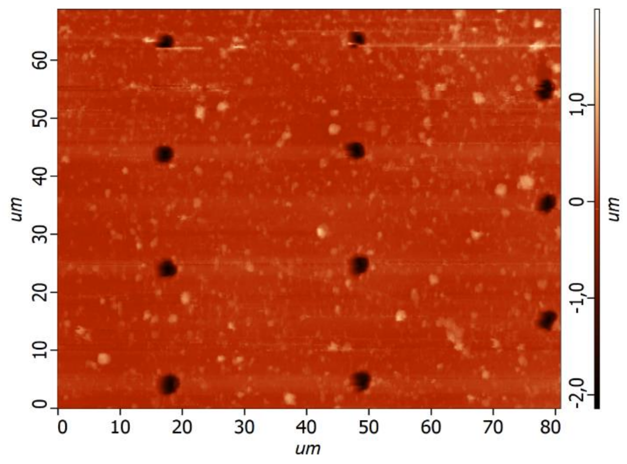
Results

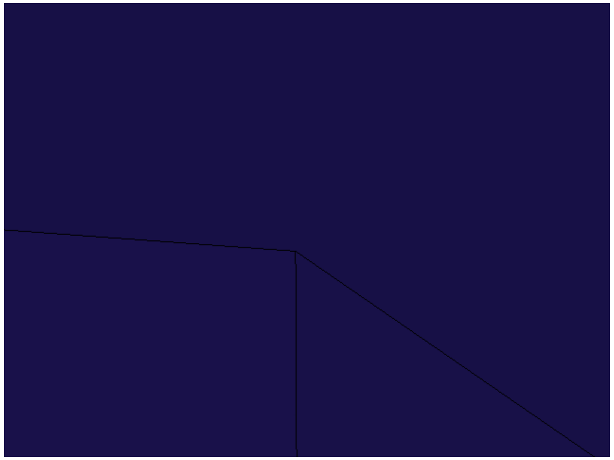


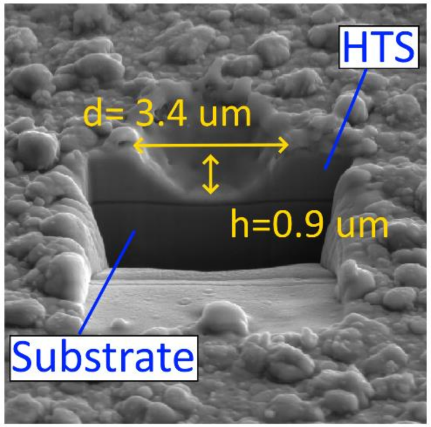
1st mode

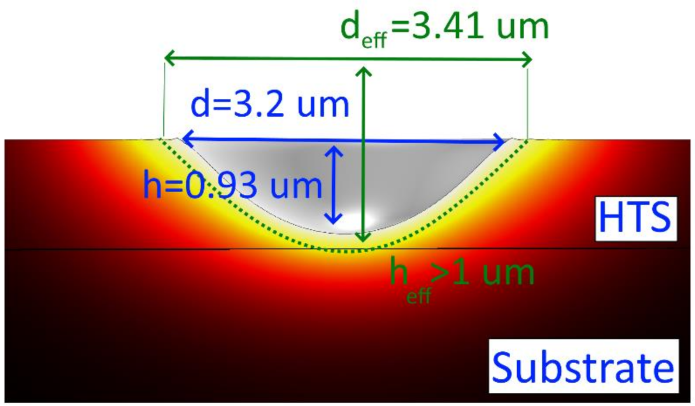


2nd mode









Conclusion

- ✓ An experimental study and a numerical analysis of the processes of formation of a defect structure in HTSC REBCO films under ultrashort laser irradiation have been carried out. Calculations and experimental studies were carried out for two modes of exposure with different focusing of the laser beam

- ✓ The features of the formation of a defect structure in the studied modes are shown. The presence of an effective defect region, namely, a non-superconducting region around the visible defect is shown

The reported study was funded by RFBR, project number 20-08-00811.


Thanks for attention