“Educational Courseware for Understanding Metal Heating Processes”

GTL 株式会社激光技術研究所

『Metal Temperature Distribution Analysis Courseware (Heat Input Model Edition)』

Version 0.1 (October 2025)

Gekitech-Labs., Inc.
Numerical Simulation and Courseware Development Committee
Date of Issue (e.g., October 23, 2025)

System Requirements (Compatible with Microsoft Excel 2021 or later)

➢ **Development Background**

Designed to help users **intuitively understand how differences in heat input distributions affect temperature distributions** within metals.

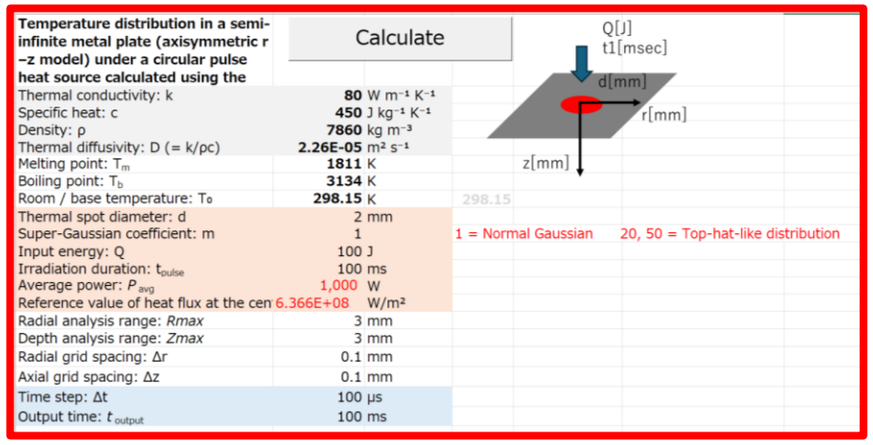
➢ **Key Features**

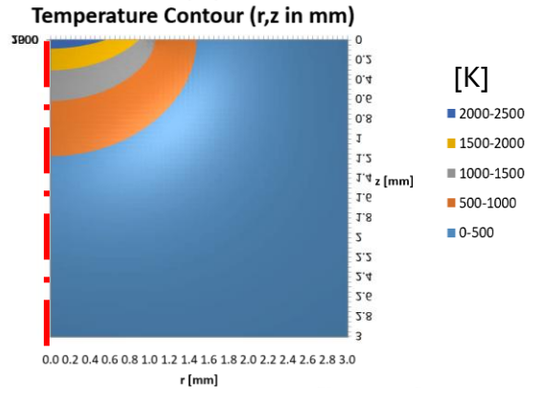
Runs entirely in **Excel-VBA** (no external software required)

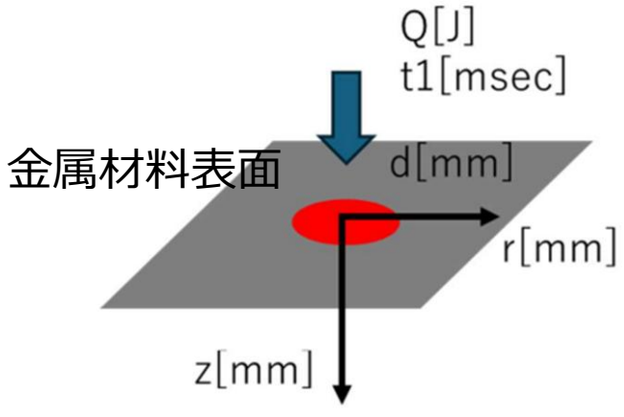
Provides **interactive simulation and visual representation** of heat diffusion

Users can freely set **material properties** and **geometric parameters** to perform simulations

Enables learners to **create customized graphs** from simulation results for deeper insight

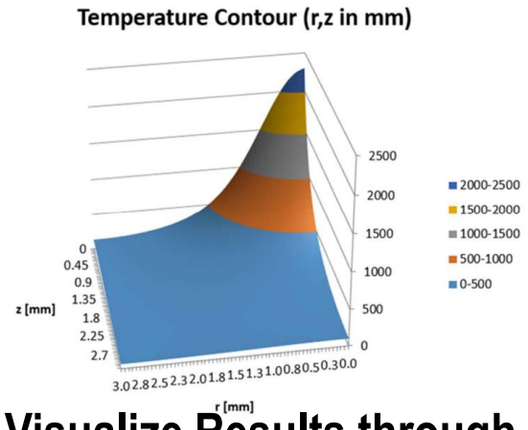






Input Heat Source Conditions

Run Simulation



Visualize Results through Graphs

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Operation Screen and Functional Overview

- **Intended Users:**
  Engineers in technical training / Students in engineering fields
- **What You Can Do**

⇒ **Set heat input conditions** and **select materials**

⇒ **Generate and visualize results** as temperature distribution graphs

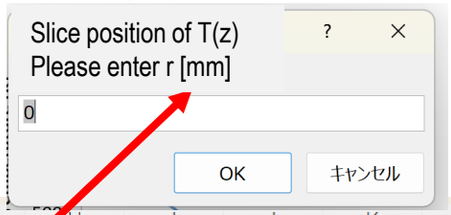
⇒ **Quickly display results** in the *Coordinate-system* sheet

⇒ **Create customized graphs directly from Excel cells**

Because all data exist within Excel, you can easily make your own plots !!

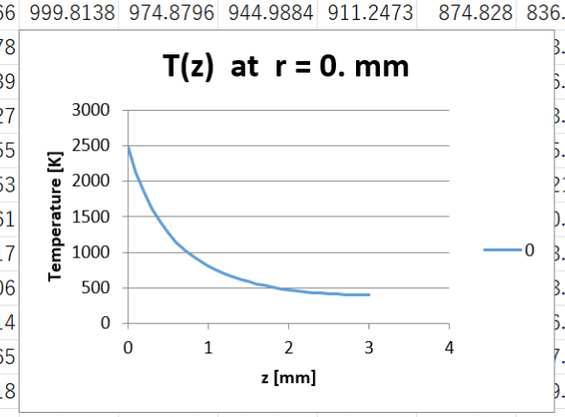
Thermal conductivity: k	**80**	W m⁻¹ K⁻¹
Specific heat: c	**450**	J kg⁻¹ K⁻¹
Density: ρ	**7860**	kg m⁻³
Thermal diffusivity: D (= k/ρc)	**2.26E-05**	m² s⁻¹
Melting point: T_m	**1811**	K
Boiling point: T_b	**3134**	K
Room / base temperature: T_0	**298.15**	K
Thermal spot diameter: d	2	mm
Super-Gaussian coefficient: m	1	
Input energy: Q	100	J
Irradiation duration: t_{pulse}	100	ms
Average power: P_{avg}	1,000	W
Reference value of heat flux at the cent	6.366E+08	W/m²
Radial analysis range: *Rmax*	3	mm
Depth analysis range: *Zmax*	3	mm
Radial grid spacing: Δr	0.1	mm
Axial grid spacing: Δz	0.1	mm
Time step: Δt	100	μs
Output time: t_{output}	100	ms

Red-colored regions indicate areas where the temperature exceeds the material's melting point

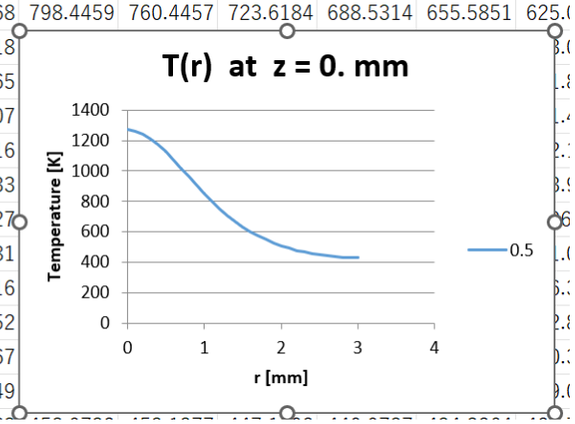


Popup menus appear with a button click, allowing **direct input of coordinate parameters**

z[mm] ↓	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3
0	2484.081	2439.704	2362.028	2245.986	2099.289	1932.421	1756.339	1580.991	1414.333	1261.875	1126.687	1009.743	910.4542	827.2365
0.1	2127.941	2092.625	2034.366	ReDraw T(z)		1576.283	1439.475	1306.957	1183.134	ReDraw T(r)			810.3274	747.1
0.2	1843.415	1816.256	1772.197			1421.513	1313.865	1207.859	1106.978				788.5132	731.5
0.3	1614.186	1593.372	1559.736	1509.699	1445.443	1370.351	1288.229	1202.831	1117.515	1035.022	957.3776	885.8916	821.2426	763.6
0.4	1427.557	1411.51	1385.567	1346.862	1296.896	1238.073	1173.139	1104.862	1035.783	968.0554	903.3548	842.8591	787.2855	736.9617
0.5	1273.992	1261.507	1241.289	1211.027	1171.768	1125.239	1073.447	1018.452	962.1901	906.3534	852.3147	801.1006	753.4035	709.6202
0.6	1146.359	1136.55	1120.633	1096.734	1065.587	1028.449	986.8036	942.1966	896.1133	849.886	804.6338	761.235	720.3255	682.3188
0.7	1039.297	1031.517	1018.866	999.8138	974.8796	944.9884	911.2473	874.828	836.8768	798.4459	760.4457	723.6184	688.5314	655.5851
0.8	948.7416	942.5136	932.3678											
0.9	871.5766	866.5487	858.3439											
1	805.3901	801.2991	794.6127											
1.1	748.2961	744.9432	739.4555											
1.2	698.8052	696.0388	691.5053											
1.3	655.7307	653.434	649.6661											
1.4	618.1188	616.201	613.0517											
1.5	585.1971	583.587	580.9406											
1.6	556.3355	554.9766	552.7414											
1.7	531.0166	529.8639	527.9665											
1.8	508.8135	507.8307	506.2118											



Temperature distribution along the **depth direction (z-axis)** from the surface
– Deviation from the center is represented by **r [mm]**



Temperature distribution along the **radial direction (r-axis)**
– Corresponding depth position indicated by **z [mm]**

Interactive Graph Update

By selecting **row or column data**, users can modify parameters such as **r [mm]** or **z [mm]** and instantly **update the plots** to examine temperature variations along depth or radial directions.

Visualization of the balance among heat input, heat conduction, cooling based on parameters such as thermal conductivity.

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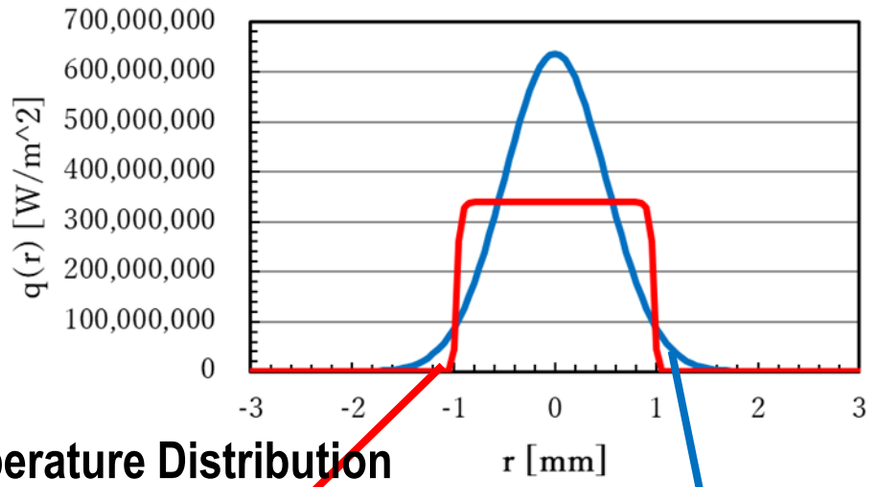
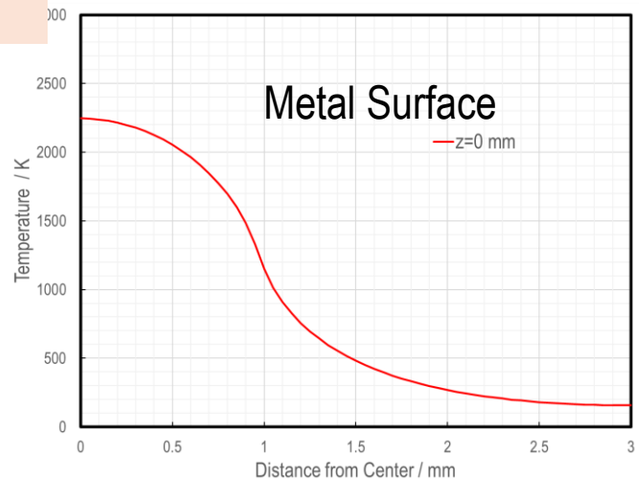
Visualization and Learning Effect

- Heat Input Profiles:
  Gaussian vs. Top-Hat Distribution



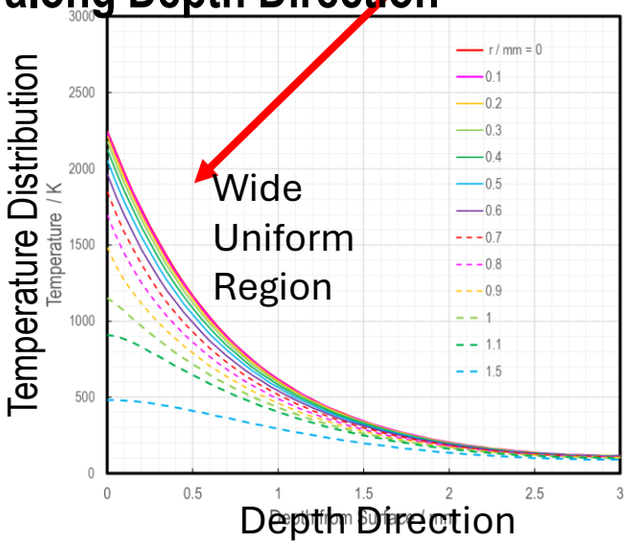
Now Supports
Ring-Shaped Beams!

Temperature Distribution along Radial Direction (r-axis)

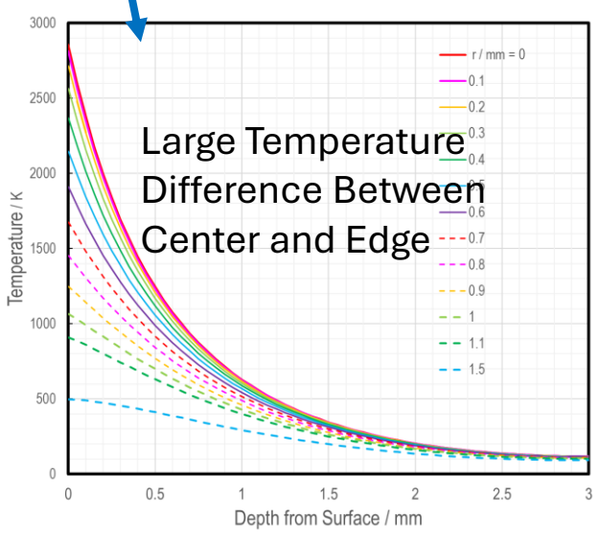


Top-Hat-Like Heat Input
Temperature Distribution

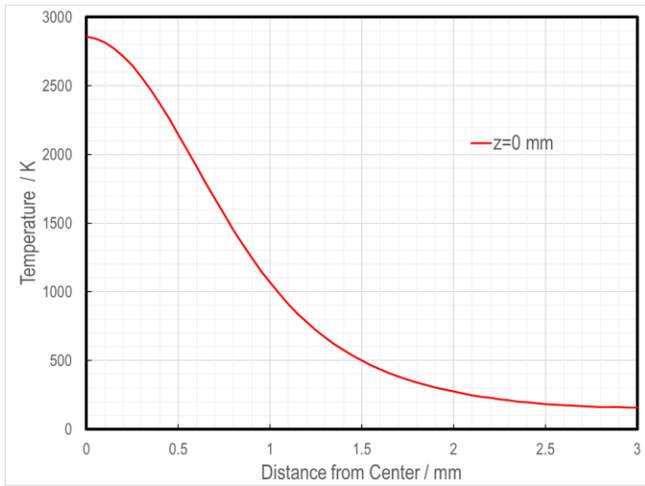
Temperature Distribution along Depth Direction



Top-Hat-Like Heat Input
Temperature Distribution



Gaussian Heat Input
Temperature Distribution



Gaussian Heat Input
Temperature Distribution

- Pulse vs (Quasi-)CW (Same Average Power Condition)
- Intuitive Understanding of Heat Diffusion
- Graphs and Temperature Distribution Maps for Each Example (with Color Scale)
- Comparison of Cooling Characteristics of Materials (Fe, Al, Cu)

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Future Development and Applications

- **Summary:**
  A Visualization Tool Bridging Education and Research

- **Future Development**

1. **Cooling process simulation** now available — complementing the heat input model! *(Freshly released!)*
2. **Solid-to-liquid phase model** under development, incorporating **temperature-dependent material properties.** *(Coming soon!)*
3. **Ring-shaped heat input** model now supported. *(Now available!)*
4. Planned expansion to include **laser heating simulation** with **temperature-dependent absorption coefficients.**
5. To be released as an **educational courseware** for **engineer training and engineering students.**