Optimization of Integration Plate for LASER Based Range Finding System using FEM

Tarun Kumar Dhiman, Pankaj Negi, Kiran Sharma, Gagan Bansal

Abstract: The design and analysis of an integration plate for Laser Based Range Finding System (LBRFS) is based on three subsystems which are going to be (payload) mounted on different locations. FEM modeling and simulation of three different configurations have been considered for integration plate in assembled payload conditions. Structural analysis of the plate under the simulated boundary conditions was carried out. Plate deflection at critical point was worked out. Depending upon the results obtained optimum plate thickness with stiffeners at the various locations was incorporated on the integration plate to meet the system requirements.

Keywords: Laser Based Range Finding System, payload.

I. INTRODUCTION

The range finding systems find wide application in meteorology, air pollution monitoring and control, military application, surveying application, oceanography etc. Unlike micro wave radar, laser beam is highly directive and can be used to measure the range of small targets. For survey purpose highly accurate range finding systems with maximum accuracy are available based on laser. The basic principle of laser range finder is to measure (to & fro) travel time of laser radiations (light) between range finder and object. If "d" is the distance of target from range finder and "t" is the time for travel of light (to and fro path), and "c" speed of light, then t= 2d/c and distance, d =ct/2.

Following are the different types of subsystems of Laser based range finding system:

1. Trans-receiver Module
2 Ranging and display Module
3. Power Supply Module

As all the above subsystems are going to be mounted on an integration plate. The design and analysis of this integration plate is quite critical from the system performance point of view. The design optimization of this plate has been carried out taking into consideration all the above three subs systems (payloads), system requirements, and working conditions. Analysis of the plate for deflection at various critical points caused by different subsystems under static and dynamic conditions was carried out using CAD tools. Taking into consideration the size, weight, and system requirements necessary supporting ribs/mechanical structure were incorporated to minimize the deflection at critical points within acceptable limits.

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[1] Vibration analysis and stability investigation of plates having mixed edge condition were conducted. [2] Series type method was used for free vibration of an orthotropic elastically constrained plate. [3] Finite strip method was used to model large deflection of plate using modified Newton-Raphson method. [4] Vibration and buckling of thin strips with mixed boundary condition using spline element method was used. [5] Generalized differential quadratic method was used and natural frequency of plate was obtained. [6] Incorporating stress singularity-based methodology for vibration analysis was considered. [7] Galerkins method was used to simulate the effect of inertia and shear deformation. [10] Evaluation of mixed and non-uniform boundary condition using generalized quadrature method was performed. [11] Free transverse vibration of rectangular plate with all boundary condition was simulated using Rayleigh method. [12] Ritz method was applied and the effect of changing Poisson ratio was studied. [13] Discrete and singular convolution algorithm was used for solving equation. [14] Study on flexural vibration of anisotropic plates, for this work domain decomposition method was used. [15] Analysis using spline fit strip method was performed. [16] Comprehensive analytical technique was used for free vibration analysis. [17] Vibrational analysis was performed using discrete singular convolution algorithm.

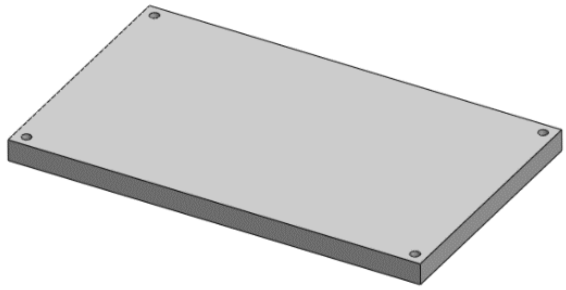

Fig.1: Integration Plate

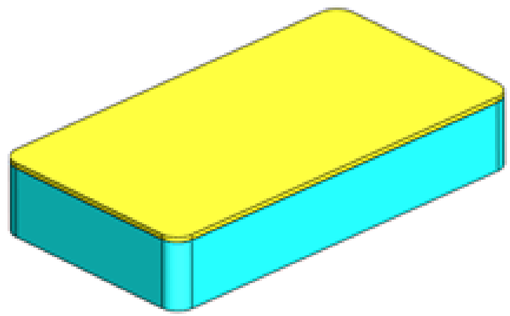

Fig.2: Dummy Load-1(4.5 Kg)

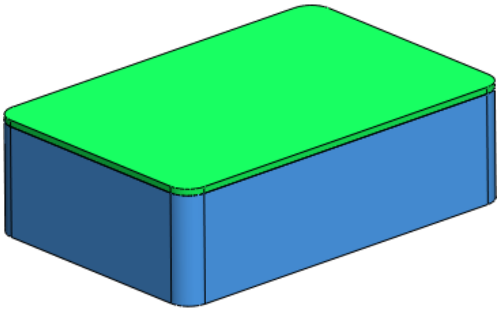

Fig.3: Dummy Load-2(3.5 Kg)

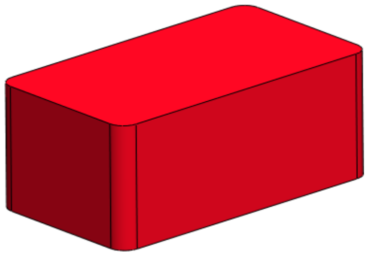

Fig.4: Dummy Load-3(4.0Kg)

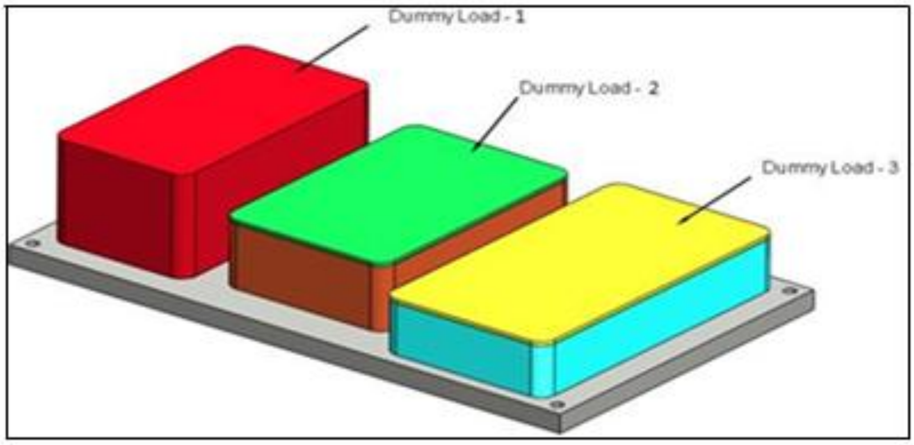

Fig.5: Assembly of Dummy Loads over Integration Plate

Integration plate model is design using CAD. Length and width of plate is around 350 mm and 210 mm. All three payloads were design and simulation is done after mounting over integration plate.

The governing equation for Eigen value analysis of the system may be cast in matrix form such that

$M\partial^2x/\partial t^2 + Kx = f(t)$………………………………………………………………………………… (1)

Where M and K are the N x N matrices, containing mass and stiffness terms, Considering the homogeneous part of Equation (1) and assuming that the displacement response isharmonic,

$X(t)=X(\omega)e^{i\omega t}$…………………………………………………………………………………………………… (2)

The structural Eigen problem can be written in the form,

$K\phi_j = \lambda_j M \phi_j$, j=1, 2, 3, 4………N……………………………………………………………… (3)

Where $\lambda j = \omega j2$ is the jth Eigen vector .Solving the above equation we can find out that natural frequency and mode shape of any system .after simulation of weight and Centre of gravity (CG) of the entire three system payload using Solid Works, models were finalized. The design analysis was carried out using Solid Works Simulation Express. After creation of finite element mesh, elements have been checked for distortion, skew ness etc. for acceptability. Materials were assigned for different components. After assigning the material properties, boundary conditions were applied as per actual conditions. Model analysis was performed by solving the above Eigen value problem. The results were displayed using postprocessing and on the basis of FEA results modifications were incorporated to meet the system requirements of less than 50micron deflection. Details of modeling and processing of different components are discussed in subsequent paragraph.

Subsystems modeling were done such that mass and Centre of gravity of actual system were retained. The modeling of the components was done by using Solid Works software and model was then imported to solid works simulation express through Initial Graphics Exchange Specification (LGES) file for the model analysis using finite element method. To achieve the optimum design of the integration plate three different configurations have been considered for the analysis of the plate in assembled payload conditions. FEM analysis was carried out to analyze the stresses developed, normal frequency and deflection of plate. The following plate configurations have been considered

Configuration 1- Plate with uniform thickness of 15mm

Configuration 2- Plate with thickness of 15mmwith 4mm ribs and material squibbed at different locations

Configuration 3- Plate with thickness of 15mm with 7mm ribs and material squibbed at different locations

II. BOUNDARY CONDITIONS

The integration plate has been fixed using four holes of diameter 8.2mm to constrain the motion in all six degree of freedoms i.e. three rotation and three translation Each subsystem payload has been mounted on the integration plate with the help of four M4 fasteners. These entire subsystems payload have been mounted on the integration plate as shown in figure 5.

The 3D solid model and wire frame CAD model of integration plate. The design analysis has been carried out using Solid Works Simulation Express. The meshed integration plate is shown in figure 6. The details of component material, type of elements, and meshing are given below.

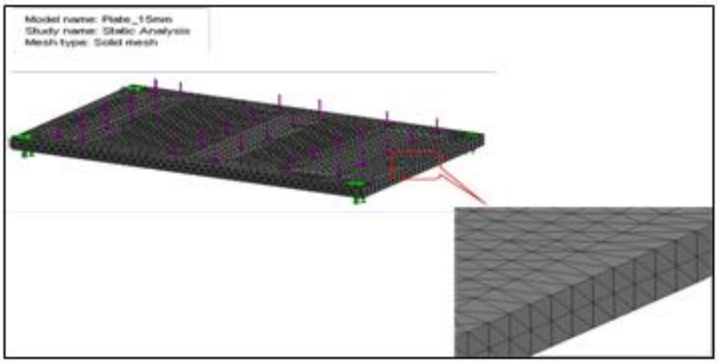

Fig. 6 Meshed Integration plate

III. FREQUENCY ANALYSIS OF PLATE_15MM_@6G

Material specifications used for analysis of LASER Integration plate.

Table: 1(Material Properties)

Material name:	Aluminum Alloy - 2219-T31	
Property Name	**Value**	**Units**
Elastic modulus	7.2e+010	N/m^2
Poisson's ratio	0.33	NA
Shear modulus	2.7e+010	N/m^2
Mass density	2840	kg/m^3
Tensile strength	3.6e+008	N/m^2
Yield strength	2.5e+008	N/m^2
Thermal expansion coefficient	2.23e-005	/Kelvin
Thermal conductivity	116	W/(m.K)
Specific heat	864	J/(kg.K)

Restraints and Loads

Table: 2 (Restraints)

Restraint name	Selection set
Restraint-1	All Holes Ø8.0 are fixed
Restraint-2	
Restraint-3	
Restraint-4	

Table: 3(Load)

Load name	Selection set
Force-1	Normal force on Top surface= 264.87 N
Force-2	Normal force on Top surface= 206.01 N
Force-3	Normal force on Top surface= 235.44 N

Table: 4(Mesh Details)

Mesh Type:	Solid Mesh
Method Used:	Standard
Automatic Transition:	Off
Smooth Surface:	On
Size:	10.323 mm
Tolerance:	0.51618 mm
Quality of Mesh:	High
Elements:	8651
Nodes:	14919

Plate, 15mm @6g – Deformation1

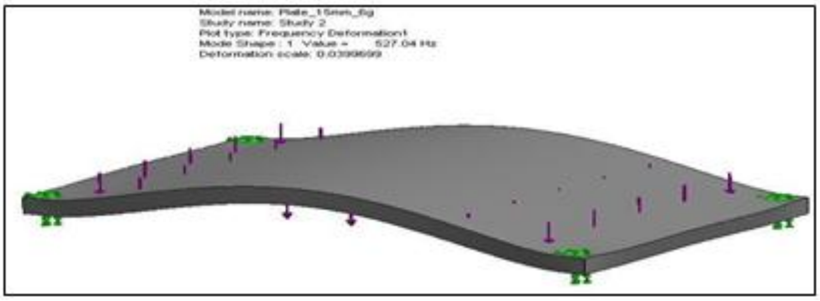

Fig. 7: Frequency analysis result-1

Plate, 15mm @6g – Deformation2

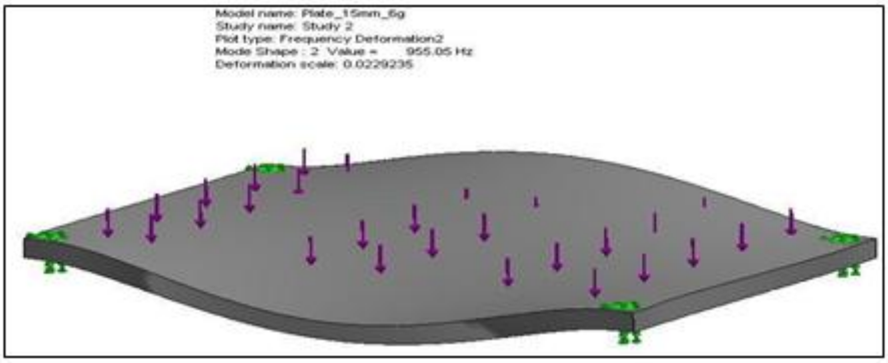

Fig. 8: Frequency analysis result -2

IV. FREQUENCY ANALYSIS OF PLATE, 15MM WITH RIB DEPTH 4MM) @6G (SAME MATERIAL)

Table: 5 (Restraints)

Restraint name	**Selection set**
Restraint-1	All Holes Ø8.0 are fixed
Restraint-2	
Restraint-3	
Restraint-4	

Table: 6 (Load)

Load name	**Selection set**
Force-1	Normal force on Top surface= 264.87 N

Force-2	Normal force on Top surface= 206.01 N
Force-3	Normal force on Top surface= 235.44 N

Plate, 15mm with rib (depth4mm) @6g - Deformation1

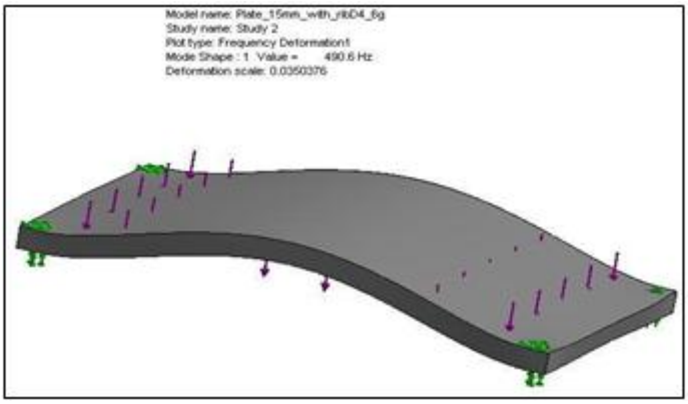

Fig. 9: Frequency analysis result-1

Plate, 15mm with rib (depth4mm) @6g -Deformation2

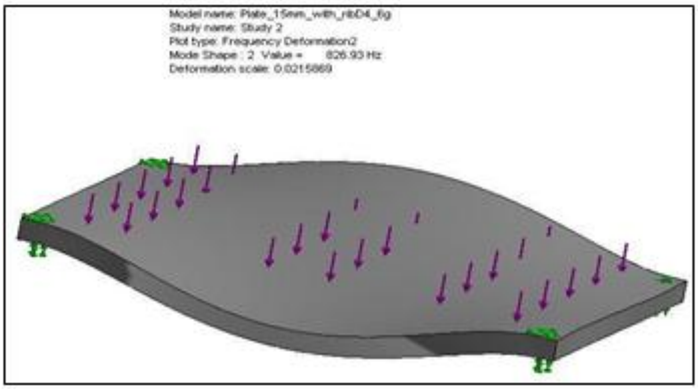

Fig. 10: Frequency analysis result-2

V. FREQUENCY ANALYSIS OF PLATE, 15MM WITH RIB (DEPTH7MM) @6G (SAME MATERIAL)

Table: 7 (Restraint)

Restraint name	**Selection set**
Restraint-1	All Holes Ø8.0 are fixed
Restraint-2	
Restraint-3	
Restraint-4	

Table: 8 (Load)

Load name	**Selection set**
Force-1	Normal force on Top surface= 264.87 N
Force-2	Normal force on Top surface= 206.01 N
Force-3	Normal force on Top surface= 235.44 N

Plate 15mm with rib (depth7mm) @6g Deformation 1

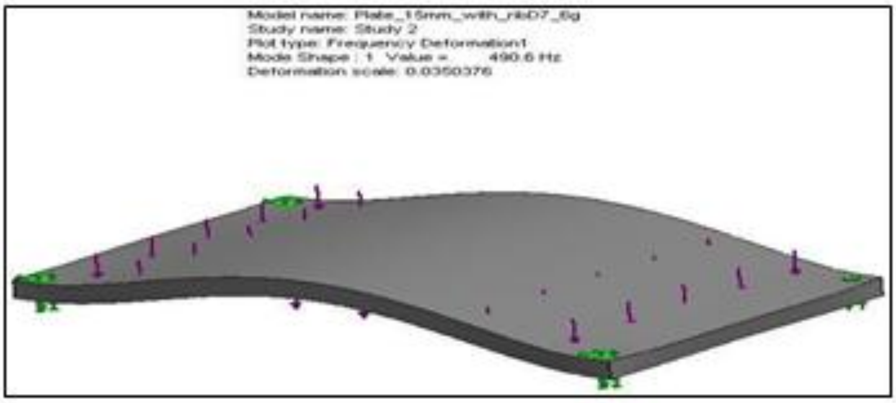

Fig. 11: Frequency analysis result-1

Plate 15mm with rib (depth7mm) @6g Deformation 2

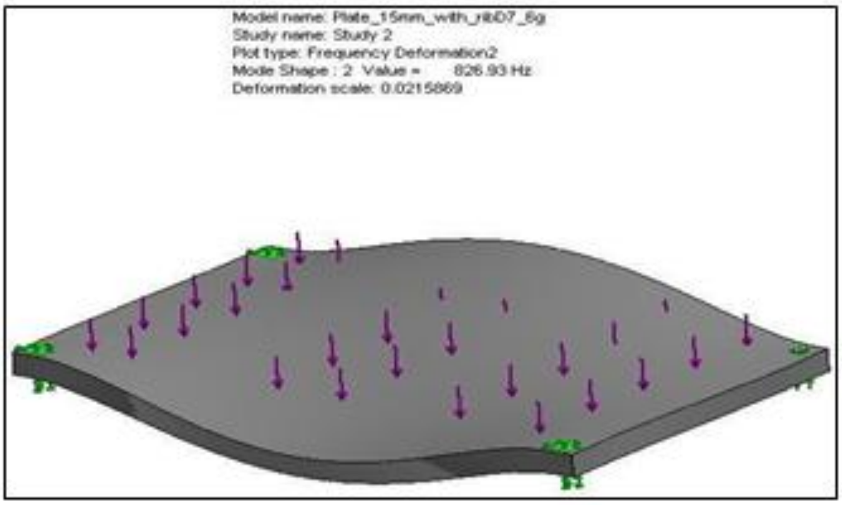

Fig. 12: Frequency analysis result-2

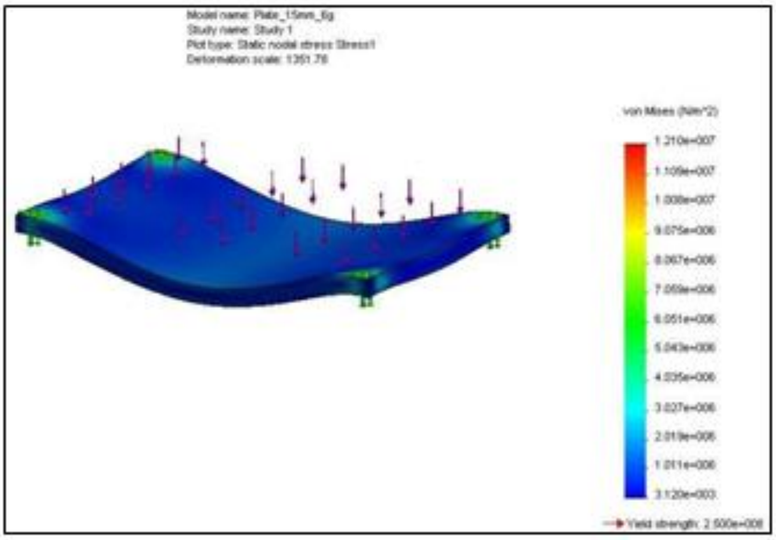

Fig. 13: Stress analysis

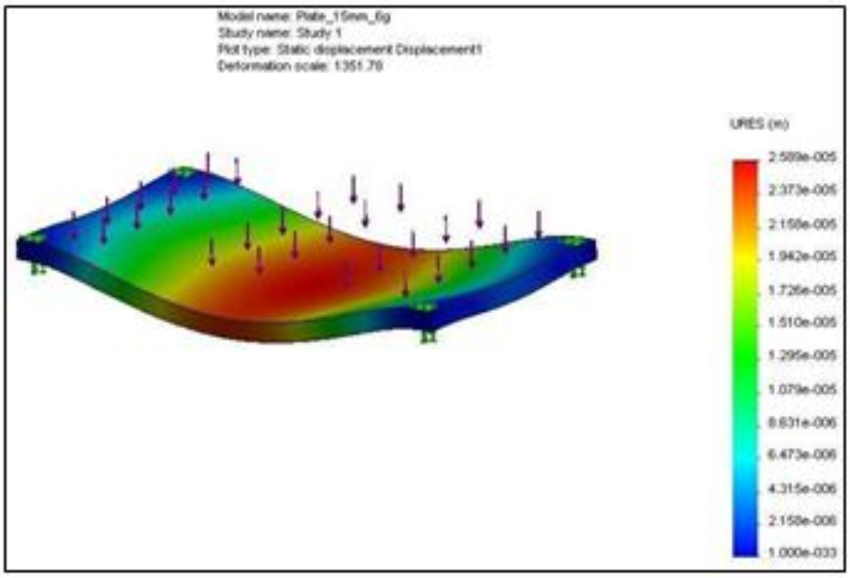

Fig. 14: Displacement analysis

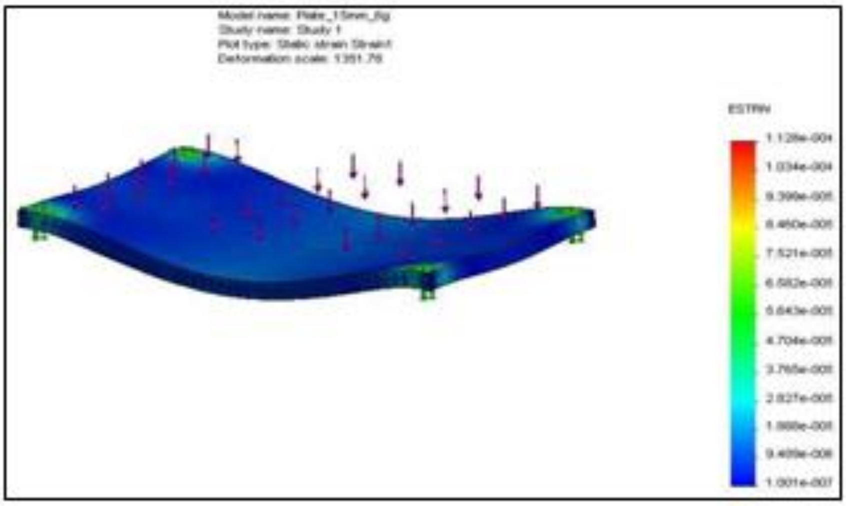

Fig. 15: Strain analysis

Table: 9 (Analysis Report)

Name	Type	Min	Location	Max	Location
Stress	VON: von Misses Stress	11602.3 N/m^2 Node: 16523	(2.770 mm, 8.709 mm, -96.127 mm)	1.38e+07 N/m^2 Node: 66	(336.061 mm, 0 mm, -199.305 mm)
Displacement	URES: Resultant Displacement	0 m Node: 1	(10 mm, 0 mm, -196 mm)	3.76e-05 m Node: 6679	(178.89 mm, 9.463 mm, -105.061 mm)
Strain	ESTRN: Equivalent Strain	6.530e-08 Element: 14495	(8.252 mm, 8.523 mm, -105.086 mm)	0.000118 Element: 11870	(336.843 mm, 0.846 mm, -14.811 mm)

VI. RESULT AND CONCLUSION:

FEM analysis of LASER based range finding system was performed. Optimization of integration plate was completed. Three different types of payloads are used over plate for analysis purpose. Model analysis was performed by solving the above Eigen value problem.

The results were displayed using post processing and on the basis of FEA results modifications were incorporated to meet the system requirements of less than 50micron deflection.

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