COMPARATIVE ANALYSIS OF DIFFERENT KINDS OF EFFECTS IN THE NANOPROBE

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Abstract

Different kinds of parasitic effects in a nanoprobe are investigated. In this paper we consider the focusing system of nanoprobe, which consists of quadrupole lenses, but basic results are also appropriate for solenoids as focusing elements. The results of the similar analysis make it possible to design a number of goal-seeking strategies for selecting the optimal beam line structure. The influence of different linear and nonlinear aberrations is investigated using analytical and numerical methods and tools. For this purpose we present the beam line propagator based on matrix formalism for Lie algebraic tools. In conclusion, some results of fulfilled modeling are analyzed.

INTRODUCTION

Basic principles of nanoprobe construction are presented at [1]–[3]. Several sets of optimal nanoprobe parameters are given at [1] and [2] for linear and nonlinear models accordingly. Fringe field influence on the load curves is considered in [3]. In this paper we summarize results of above mentioned papers and discuss some additional problems for the nanoprobe systems design.

The approach, described in [1] allows us to find a set of embodiments for optimal nanoprobe systems in the frame of ideal linear approximation. The next paper — [2] deals with nonlinear approximation of motion equations (up to third order effects). This step gives us additional information about a "quality" of the selected examples of our focusing system. This information can help to select the most appreciate options for the focusing system. Indeed, in spite of the fact that the correction procedure, described in [2], permit to reduce the nonlinear effects, some of optimal variants of the steering parameters cannot be realized on the practice.

For the selected parameters set on the third step we consider the influence of fringe field contribution to forming of beam image. This influence can play a decisive contribution to beam spot forming. In the following we discuss some problems, which can essentially influence on the selection beam line parameters.

COMPARATIVE ANALYSIS OF DIFFERENT EFFECTS

Basic requirements for the focusing system

As pointed in the paper [1] we based on the following requirements:

> *the system should guarantee the image compression: $DM_{nl} = \gamma < 1$;*
> *the system should guarantee the focusing from "point to point";*
> *"round beam" passes into "round beam";*
> *the beam propagates without particle losses.*

For the nanoprobe focusing systems the focusing parameter γ (see the first requirement) should be less 0.01. In the contrary case we can say only about microprobe systems. The second requirement leads to a possibility of "working distance" selection (see [1]) — g. It should be observed that this parameter can be set a special controller for control the target placement.

The third requirement is a most important, because it guarantees the round form of the beam spot on the target. This requirement is important for many practical applications. As it is shown in [1] this leads to so called "load curves" for four lenses system and to "load surfaces" for systems with greater number of control lenses.

An analysis of the governing conditions

Let us consider the listed conditions, which determine the quality of our focusing system. As mentioned above we use four governing conditions. The first three of them the third apply basic restrictions. If these conditions carry out with some errors, this can leads to distortion of the quality of our focusing system. Sources of distortion (described in the papers [2, 3]) of the governing conditions play a different role.

The nonlinear effects give a main contribution to beam distortions, see, for example, [2]. But there is a possibility to reduction similar undesirable influence. It should be mention that this way is worth too much. As discussed in [2] the important contribution is made spherical aberrations. The chromatic aberration can be decreased using some procedures for enhancement of chromaticity of a beam source.

Influence of fringe fields, as described in [3], leads to the load curves distortion. In another words the "working points" for lens excitations (in our case k_1 and k_2 can move). If a researcher has a false information on fringe field distribution, it can lead to essential distortion of the resulting beam spot. Here there are two ways.

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The first way is based on a preliminary experimental treatment, which allows to obtain the necessary information about a fringe field distribution and to include it into the mathematical model, describing the nanoprobe focusing system. The inclusion this information can be realized in according to the following rules.

At first a researcher should find a model function, which approximates known experimental data with the necessary precision. Then he evaluates necessary computational procedures with the aim of definition what fringe fields characteristics play the main role. At last, on the third step, he has to do some recommendations (if it is possible) to lens manufacturers. This allows producing steering lenses with desired characteristics and to obtain the desired results.

On the second way, we can select more correct values of k_i, $i = 1, 2$, which own to a new (distorted) load curve and thereby to decrease the influence of fringe field effects. In this case we should additionally study all optimal points and select the points, which lead to the best variants of the output beam spot.

The problem of tolerances for steering elements

Let us remember the list of main variable parameters for our focusing system. Here there are two groups: the lens force parameters (excitation) k_i and geometrical parameters (drift lengths) "pre-distance" a, drift lengths s, λ and "working distance" g. It is evident that during manufacturing and adjustment processes one can not to set the nominal parameters without errors. Besides, the exploitation conditions also can lead to parameters deviations. From here it is obvious.

It should be noted that there is a problem, which play one of the key roles — the problem of tolerances for steering elements. Here we mean both lenses and drifts. Possible deviations of setup parameters can destroy an optimal working regime for our focusing system. The sensitivity of optimal variants depends on the selection of lens excitations (in our case k_1 and k_2) and geometrical parameters, which determine the chosen optimal variant. Here we should note that the number of "optimal points" on the $k_1 - -k_2$-plane depends on values of other parameters. For example for the $\lambda = 0.5$ and $g = 1$ there is only one optimal point $k_1 = 1.37420931269436$ and $k_2 = 1.0069624867793274$.

As a first example we consider the influence of "working distance" a. As one can see on Fig. 1 within the limits from 130 up to 150 (here, as in [1, 3] a is measured in units of L) the linear demagnification varies enough essentially(see Fig. 1). Here we can see, that the value of DM_{nl} change its sign in dependence on the selected optimal point.

In another words rather small variations of a leads to very small variations of the demagnification. The additional requirements ($m_{11} = m_{22}$ and $g = g_{\text{techn}}$) do not practically change. The change of "working distance" g is enough essential in depending on value of synchronous deviations for excitations k_1 and k_2 (see Fig. 2). But the

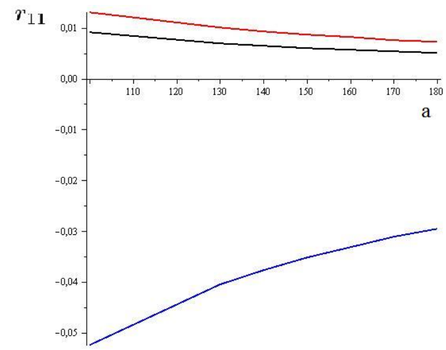

Figure 1: Dependence of the linear demagnification DM_{nl}=r_{11} on "pre-distance" a under three optimal points.

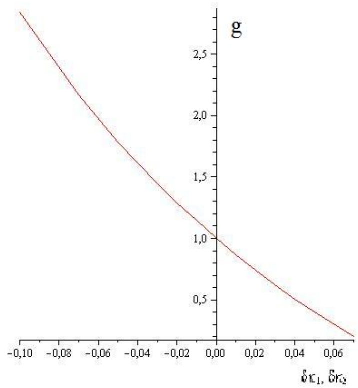

Figure 2: Dependence of "working distance" g on deviations of k_1 and k_2 for one of the optimal points.

dependence nature for some other values of parameters of the focusing system, for example the other value of λ we may receive very different picture. As an example of similar sensitiveness is demonstrated on Fig. 3 for $\lambda = 1$. On

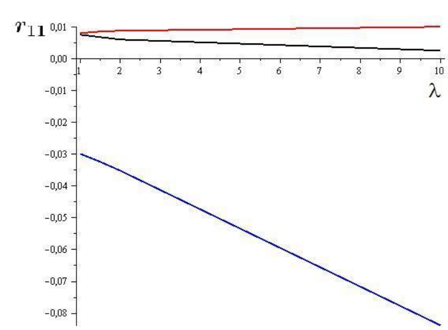

Figure 3: Dependencies of r_{11} on λ for different optimal points on the k_1–k_2 plane.

Fig. 4 one can see a significant difference between dependence for different optimal points. Here we present a plot for only two points, as for the third point is absent for corresponding parameters.

The above demonstrated pictures allow us understand,

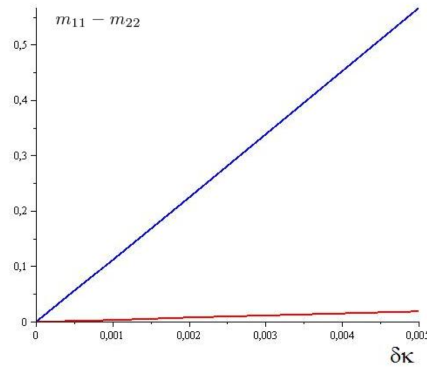

Figure 4: Dependencies of $m_{11} - m_{22}$ on deviations of k_1 and k_2 for different optimal points on the k_1–k_2 plane.

that the main characteristics ($m_{11} - m_{22}$, r_{11} and the focusing condition) have a behavior difference for different values of selected optimal points in the space of control parameters.

CONCLUSION

As above described it is necessary to consider tolerances of setting parameters, which usually selected by researcher for optimal working regime of nanoprobe focusing systems in linear or nonlinear models. Every similar facility (as nanoprobe) should be modeled individually using necessary requirements and available resources. A set of optimal points for a nanoprobe focusing system, which could be obtained using e. g. [1] methodology, has to be investigated on sensitivity. Indeed above described sensitivity of several optimal points could be heavily distinguish (see Figs. 1, 3–4).

REFERENCES

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