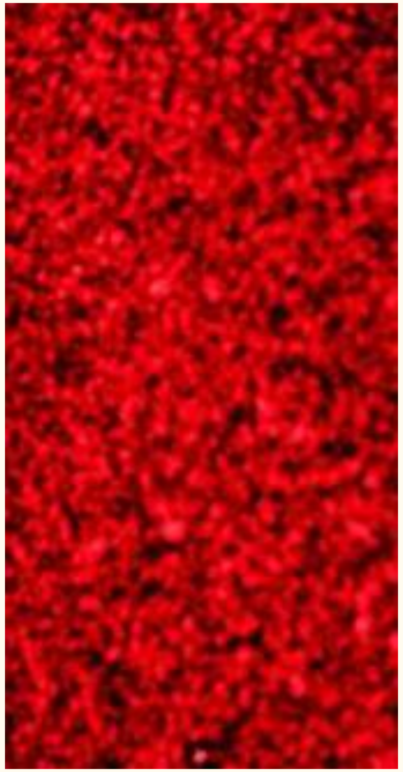
漂移的散斑

李明达、马怡阳、李缘嘉

目录 Contents

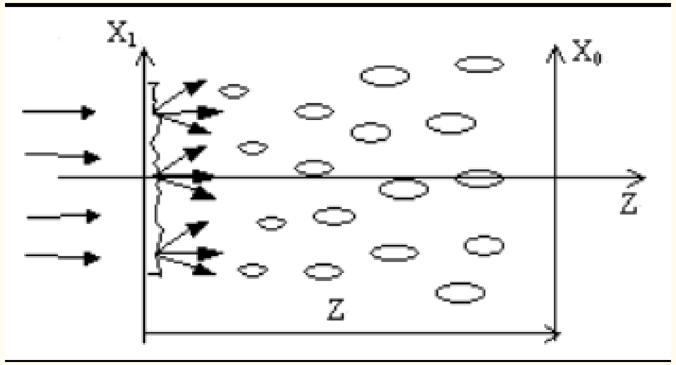
目录 Contents

一、散斑漂移原理的猜想



激光散斑的基本概念：

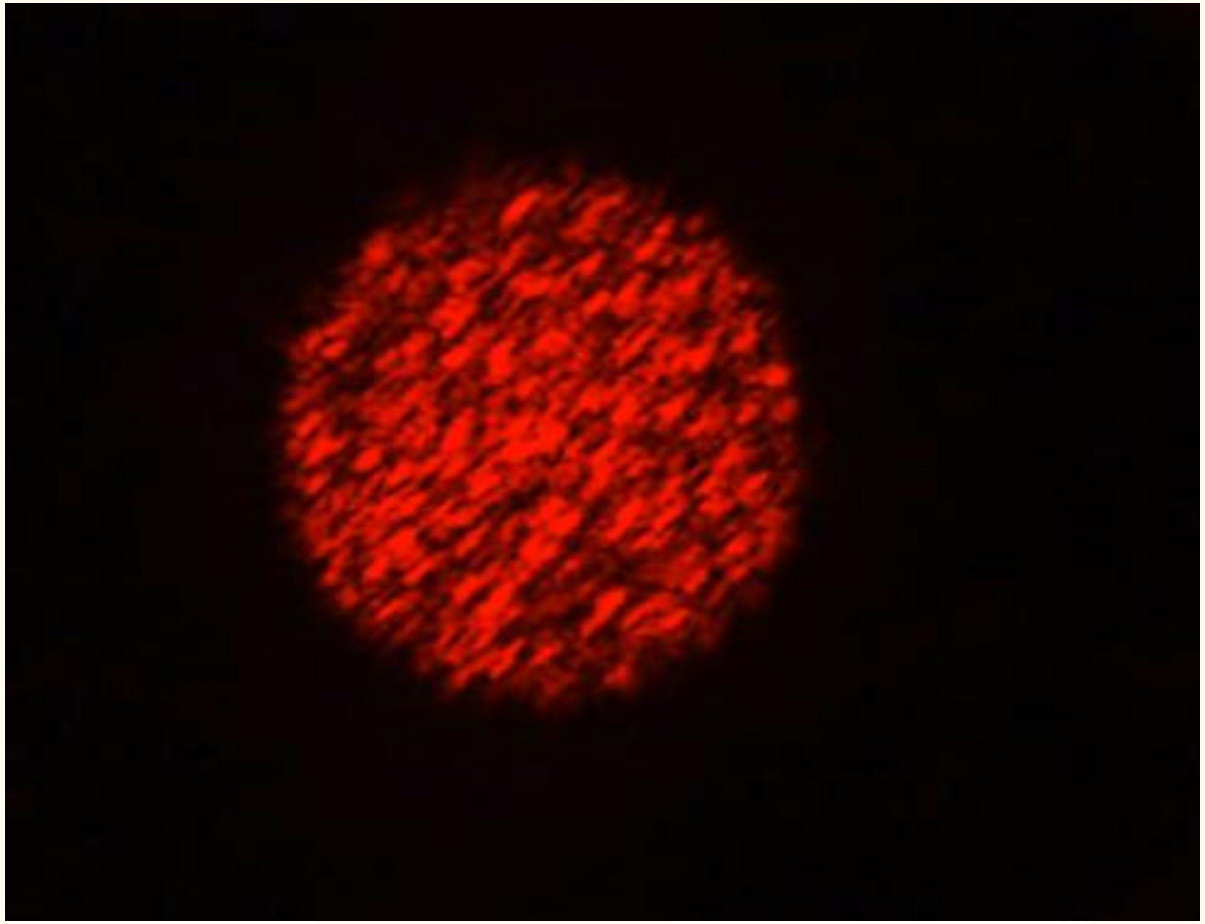
激光自散射体的表面漫反射或通过一个透明散射体（例如毛玻璃）时，在散射表面或附近的光场中可以观察到一种无规分布的亮暗斑点，称为激光散斑（Laser Speckles）或斑纹。如果散射体足够粗糙，这种分布所形成的图样是非常特殊和美丽的。

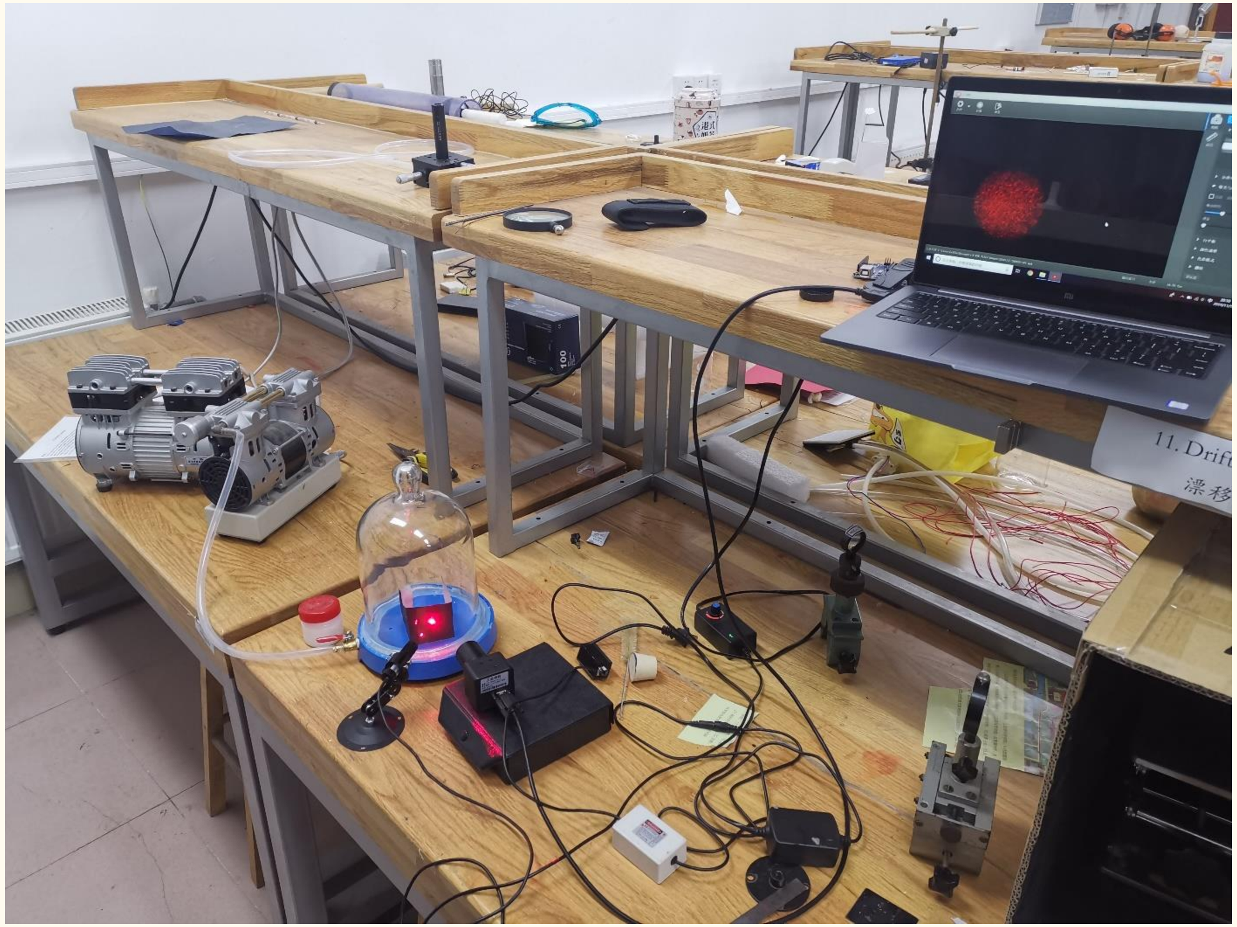


形成机制：

振幅和相位不同的相干光在空间干涉形成空间散斑

一、散斑漂移原理的猜想





一、散斑漂移原理的猜想

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Time-drift Effect of Laser Speckle

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Abstract: The time-drift effect of laser speckle was reported. A speckle model was introduced. The validity was verified by the statistical properties of intensity and argument of the complex amplitude at the observation plane. Based on this speckle model and correlation method between speckle patterns, nearly all physical factors which may result in the time-drift effect of speckle according to experimental parameters were simulated. The results show that two factors, which vertical-cavity surface-emitting laser (VCSEL) and charge coupled device (CCD). Other factors such as fluctuation of laser intensity, changes of wavelength of light and air refractive index, etc., only bring tiny changes of speckle pattern, or even do not cause the time-drift effect of laser speckle at all.

Key words: Speckle; Time-drift effect; Correlation coefficient
CLCN: TN248; TN249 **Document Code:** A **Article ID:** 1004-4213(2009)03-523-5

0 Introduction

It is well-known that laser speckle arises when coherent light is scattered by optically rough surfaces. The surface elements change the amplitude, phase, polarization of each of the sub wavelets due to random structure of the surface. Thus, a high-contrast grainy pattern with non-uniform size and brightness appears on CCD[1-3]. Compared with traditional sensing technology, sensing technique based on speckle has many advantages, such as delicate, simple and compact, so it has been widely used in measuring displacement, velocity[4-8]. Recently, many researchers have studied wet paint drying process based on time evolution effect of speckle pattern[9]. More interesting, we have found that speckle pattern varies with time slowly and deviates from the initial one gradually even though all the macro-conditions remain, which is the key of time-drift effect of laser speckle referred in the paper. A typical example from which time-drift effect of laser speckle could be observed is laser speckle mouse (LSM). When laser speckle mouse works on certain surfaces, displacement value of cursor on display is calculated by movement between speckle patterns. In principle, the position of cursor wouldn't change if no relative movement between LSM and surface occurs, but it's not difficult to find the position of cursor would deviate from the initial position as time passes. The time-drift effect of laser speckle as mentioned above is responsible for the phenomenon. In the paper, we report the time-drift effect of laser speckle firstly and then analyze factors that may cause the effect, which is not only necessary to understand the effect better, but also more important to propose suggestions of prohibiting the effect on the occasion such as LSM or decreasing measuring error induced by the effect on other occasions.

1 Introduction of the effect and theoretical analysis

1.1 Introduction of the effect

Fig. 1 shows the experimental set-up. A linear polarized single-longitudinal mode VCSEL with wavelength of 850 nm (OSRAM F497A) is biased at 6.4 mA and power 0.96 mW, and a spherical lens with focal length about 2 mm in front of VCSEL is used to collimate illumination light on the white paper surface with beam diameter about 2 mm. Incident Light and receiving direction are 26° and 30° with the surface normal respectively, and distance between surface and CCD is 7.5 cm. A linear polarizer P1 in front of CCD ensures fully polarized developed speckle received. Temperature of the room is about 20 ℃. A CCD (SONY XC-73CE) is used to receive the interference light

Fig. 1 Schematic diagram of the experimental set-up

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该论文指出了六种可能导致散斑漂移的原因：
（1）激光器光强度随时间变化
（2）激光器波长随时间变化
（3）空气折射率随光路的时间而变化
（4）由于激光照射的表面的热效应而引起的表面微结构的扩展
（5）由于温度升高，CCD每个像素的光度随时间变化
（6）由于吸收散射光能引起的温度升高导致CCD的噪声增加

文中认为（4）和（6）是主要因素，但这两个主要因素并不能满足**定向**漂移，所以经过我们对这六个因素分析，得出了我们对散斑定向漂移的猜想。

一、散斑漂移原理的猜想

我们对定向漂移的猜想：

表面空气被加热，从而密度变小

这部分空气折射率变化

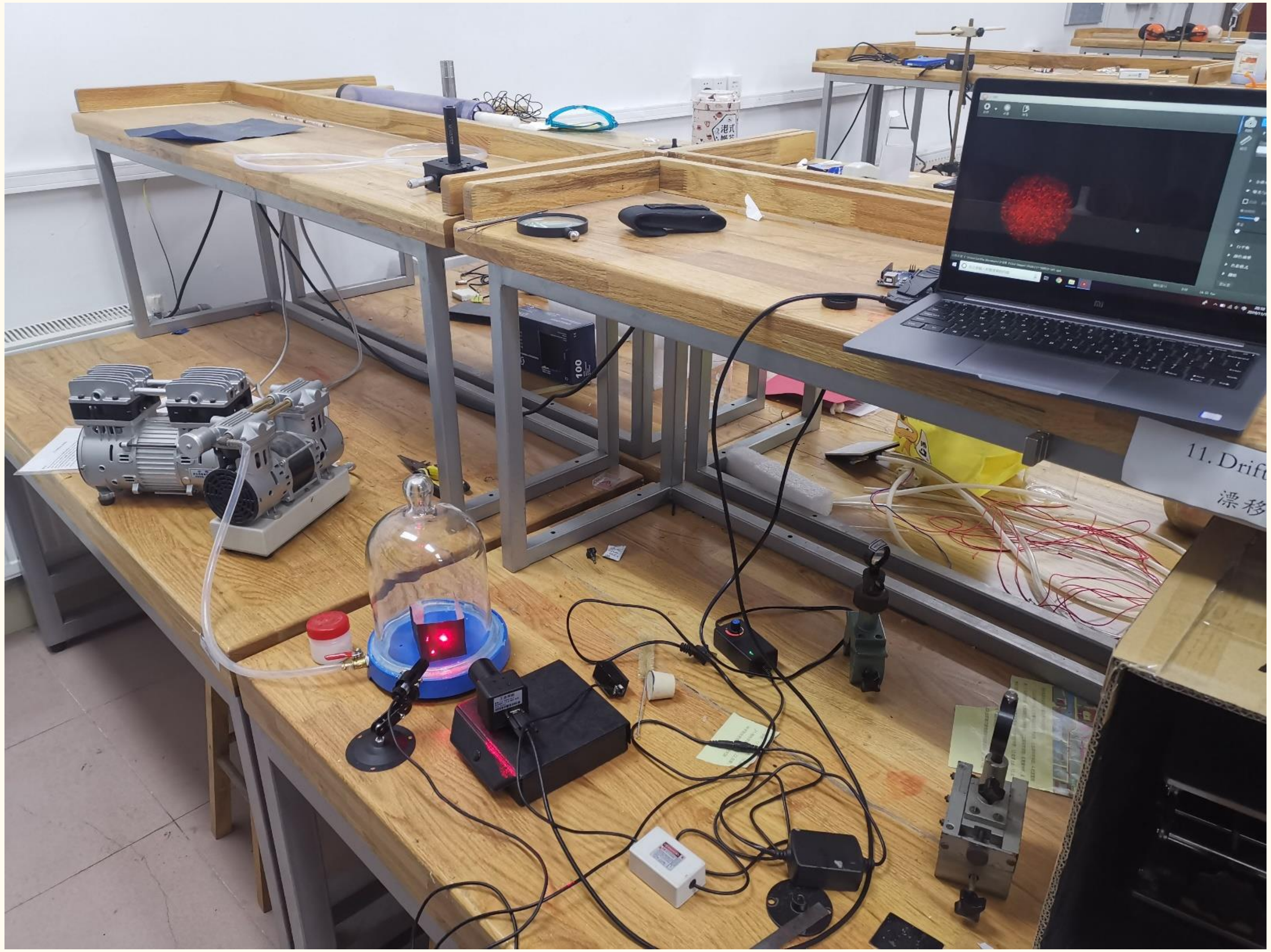
密度变小从而上升

折射率变化的空气定向流动

干涉光程差随定向移动改变

目录 Contents

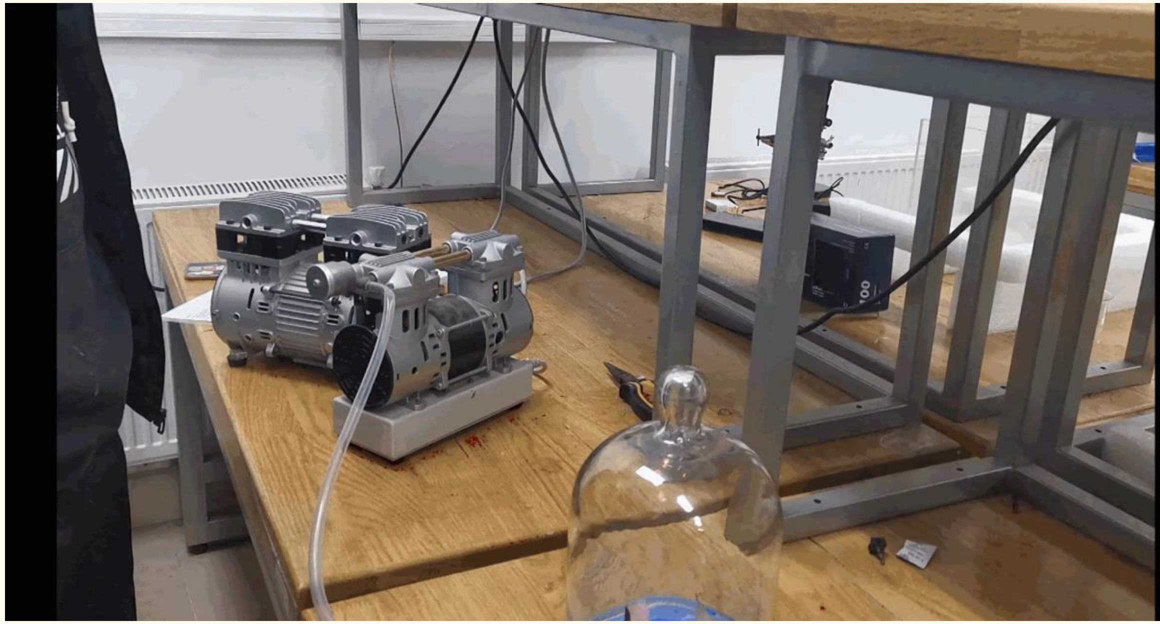
二、对猜想的验证

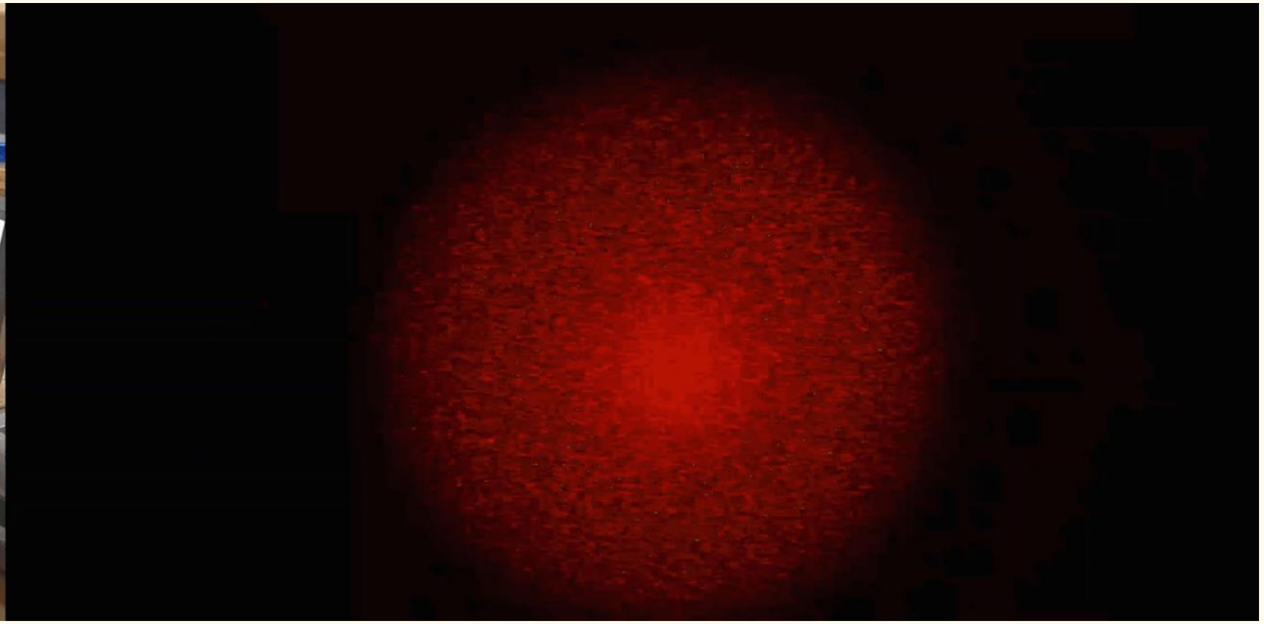


- 实验仪器：
- 1. 半导体激光器
- 2.CCD相机+电脑
- 3.真空系统（真空罩、真空硅脂等）
- 4. 真空泵
- 5. 黑色纸以及其他材料

二、对猜想的验证

二、对猜想的验证





抽真空前有较为明显的散斑漂移，抽真空的过程中空气剧烈震荡，导致散斑剧烈飘动。
但真空抽好之后，漂移速度明显降低，**几乎不动。**

因此验证了**空气加热导致漂移**猜想！

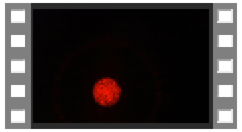
目录 Contents

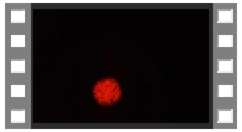
三、散斑漂移依赖于哪些因素

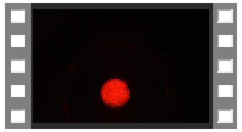
我们主要研究了在常压下，散斑漂移**速度**和**材料**、**光强**的关系。

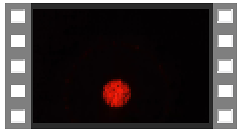
材料分别是：黑纸，粗糙纸，塑料，磨砂纸，铁片

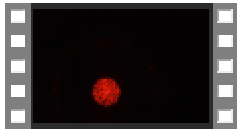
光强分别是：强光强，弱光强


粗糙纸.mp4


黑纸.mp4

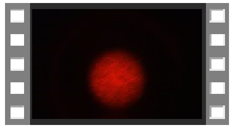

磨砂纸.mp4

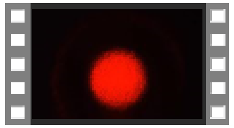

塑料.mp4

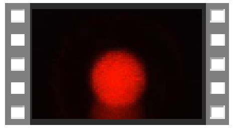

铁片（无现象）.mp4

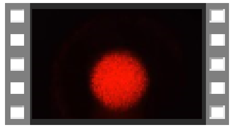
强光强

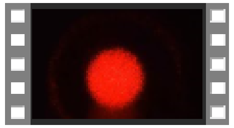
弱光强


粗糙纸.mp4

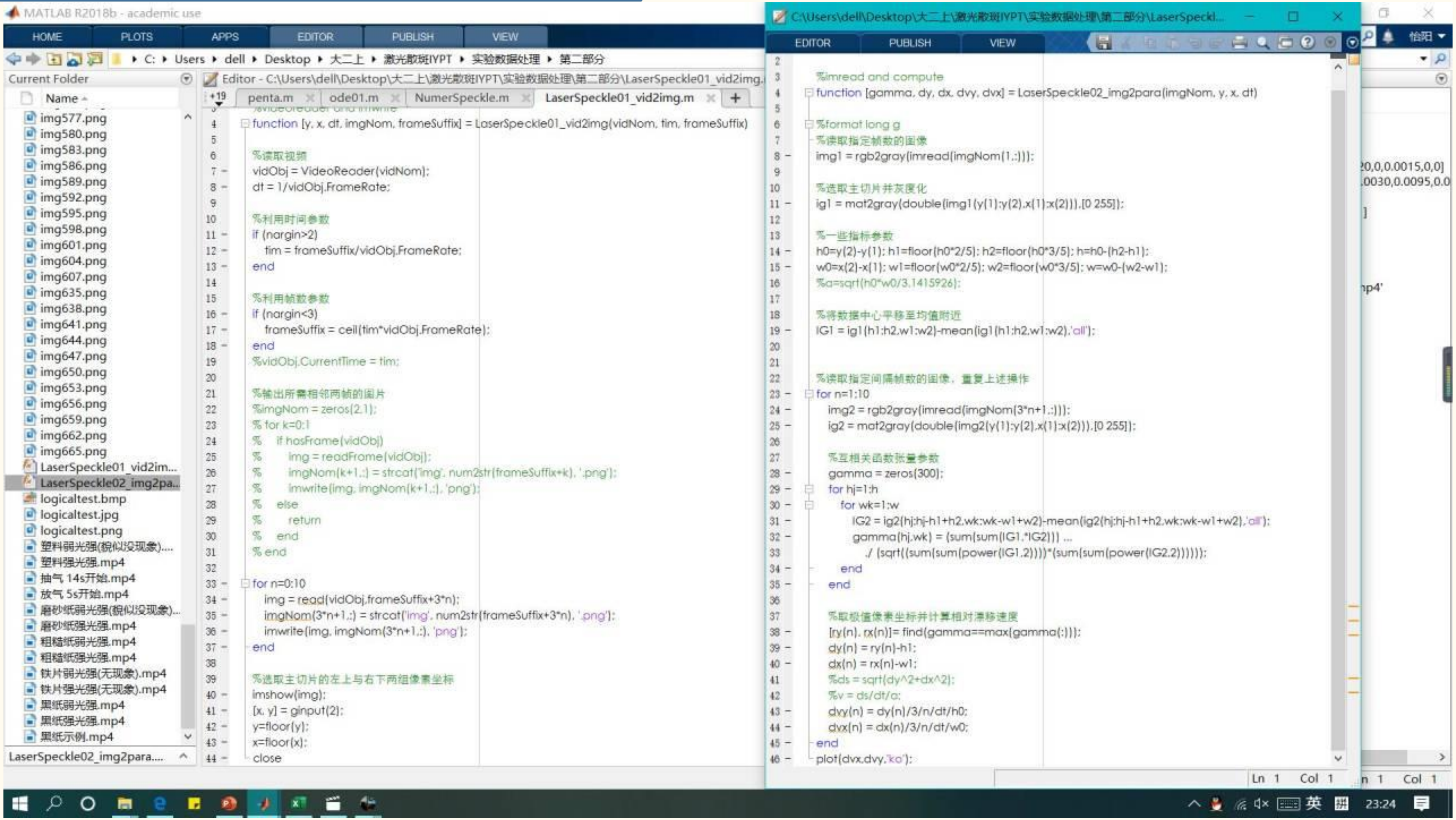

黑纸.mp4


磨砂纸(貌似没现象).mp4


塑料（貌似没现象）.mp4

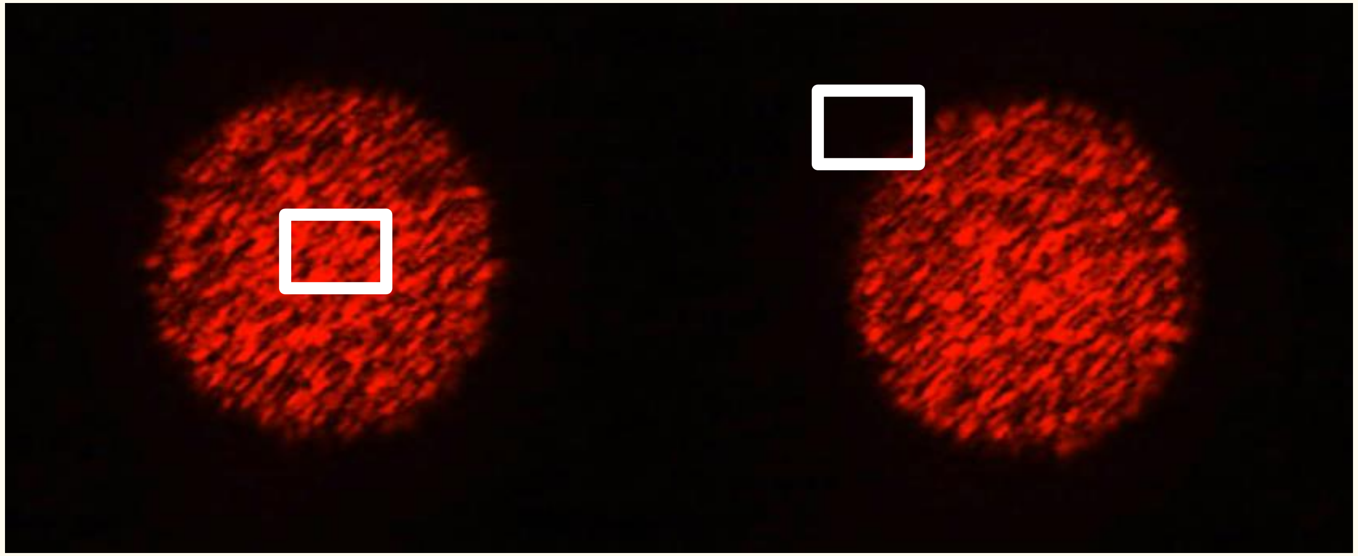

铁片（无现象）.mp4

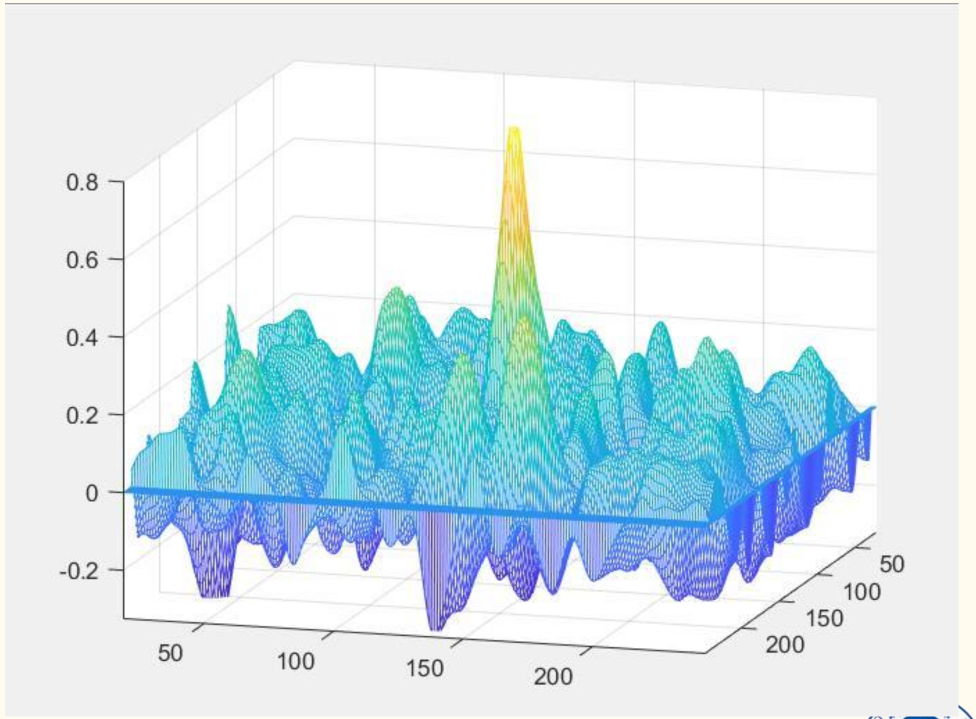
三、研究通过Matlab实现



三、实现的算法

t_1时刻　　　　　　t_2时刻



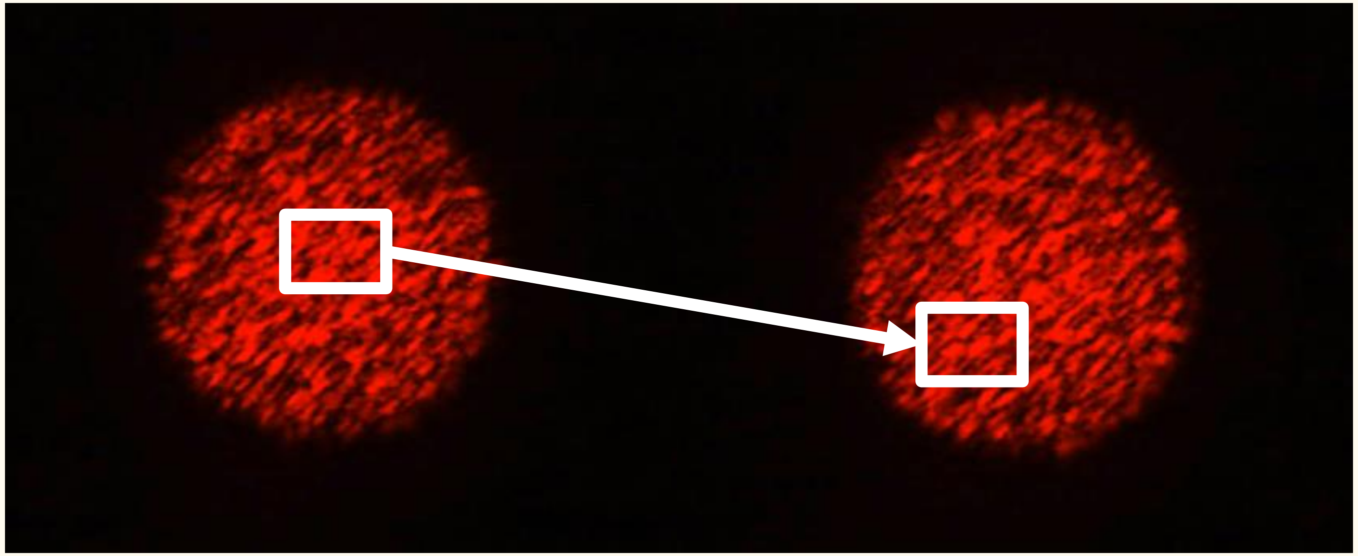


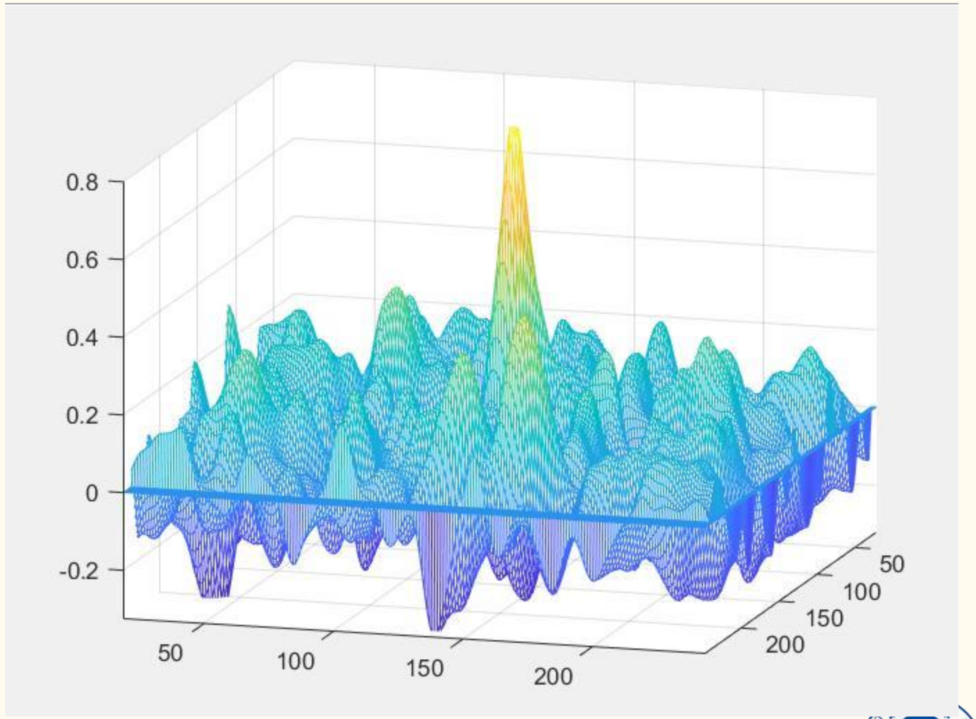
两同面积区域算互相函数

$$\gamma=\frac{\sum_{x_i}\sum_{y_i}\left(I_1(x_i,y_i)-\langle I_1(x_i,y_i)\rangle\right)\left(I_2(x_i,y_i)-\langle I_2(x_i,y_i)\rangle\right)}{\sqrt{\left(\sum_{x_i}\sum_{y_i}\left(I_1(x_i,y_i)-\langle I_1(x_i,y_i)\rangle\right)^2\right)\left(\sum_{x_i}\sum_{y_i}\left(I_2(x_i,y_i)-\langle I_2(x_i,y_i)\rangle\right)^2\right)}}$$

三、实现的算法

t_1时刻　　t_2时刻



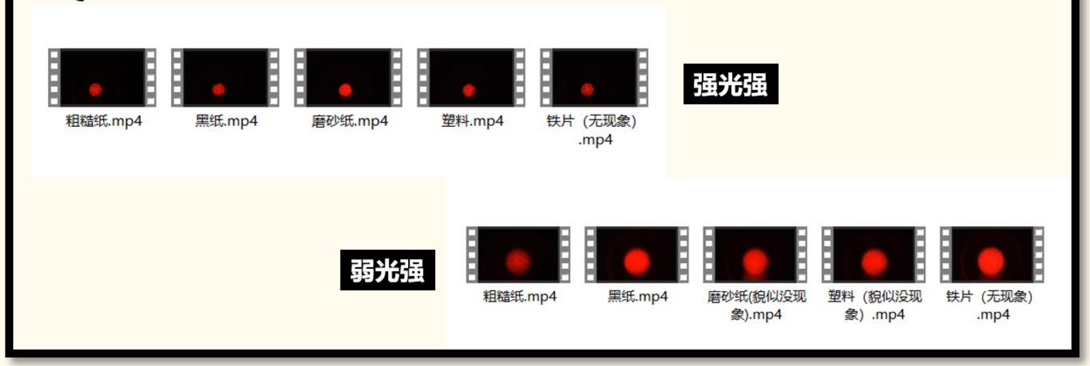


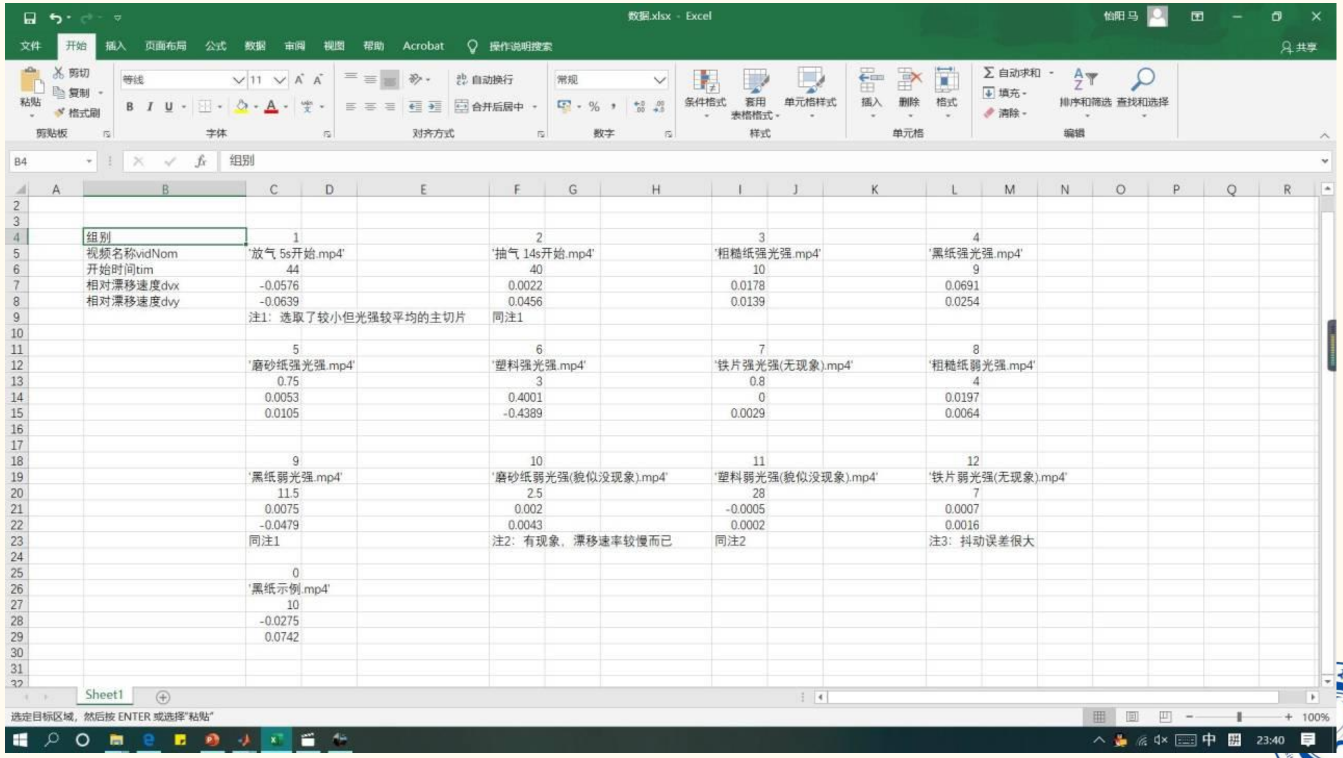
再通过算这两块区域的 Δx 和 Δy 即可得出漂移速度

三、得出Δx，Δy并得出速度

材料分别是：黑纸，粗糙纸，塑料，磨砂纸，铁片

光强分别是：强光强，弱光强





组别	1	2	3	4
视频名称vidNom	'放气 5s开始.mp4'	'抽气 14s开始.mp4'	'粗糙纸强光强.mp4'	'黑纸强光强.mp4'
开始时间tim	44	40	10	9
相对漂移速度dvx	-0.0576	0.0022	0.0178	0.0691
相对漂移速度dvy	-0.0639	0.0456	0.0139	0.0254
	注1：选取了较小但光强较平均的主切片	同注1		
	5	6	7	8
	'磨砂纸强光强.mp4'	'塑料强光强.mp4'	'铁片强光强(无现象).mp4'	'粗糙纸弱光强.mp4'
	0.75	3	0.8	4
	0.0053	0.4001	0	0.0197
	0.0105	-0.4389	0.0029	0.0064
	9	10	11	12
	'黑纸弱光强.mp4'	'磨砂纸弱光强(貌似没现象).mp4'	'塑料弱光强(貌似没现象).mp4'	'铁片弱光强(无现象).mp4'
	11.5	2.5	28	7
	0.0075	0.002	-0.0005	0.0007
	-0.0479	0.0043	0.0002	0.0016
	同注1	注2：有现象，漂移速率较慢而已	同注2	注3：抖动误差很大
	0			
	'黑纸示例.mp4'			
	10			
	-0.0275			
	0.0742			

三、散斑漂移依赖于哪些因素

Matla变截面
算法示意图
算出结果图
Excel原数据表格
我自己整理

通过对移动速度的分析，得出了下面表格中的结论，这也是**符合我们的猜想**的！

移动速度(相对值)	**黑纸**	**塑料**	**粗糙纸**	**磨砂纸**	**铁片**
强光强	1	0.81	0.35	0.16	0.039
弱光强	1	0.79	0.31	0.15	0.025

目录 Contents

四、研究方法和总结

本实验我们主要涉及的研究方法有：

1. 文献调研
2. 提出猜想
3. 实验验证：抽真空、CCD取数据等
4. 结果分析：Matlab设计程序和算法、互相干函数、数据分析

总结

本实验我们研究激光散斑漂移的原因，以及漂移依赖的因素，经过我们的猜想推理验证，我们的结论是：激光散斑漂移的原因是空气被加热，从而影响折射率，致使光程形成规律的改变，从而形成稳定漂移。

——提问环节

THANKS！

李明达、马怡阳、李缘嘉