

学校编码: 10384

分类号\_\_\_\_\_密级\_\_\_\_\_

学 号: 19920111152728

UDC\_\_\_\_\_

厦 门 大 学

硕 士 学 位 论 文

基于 FTS 的透镜阵列加工  
技术与装置实现

Research on The Machining Technology of Lens Array  
Based on FTS and The Machining Equipment Development

常小龙

指导教师姓名: 彭 云 峰

专业名称: 机 械 工 程

论文提交日期: 2 0 1 4 年 4 月

论文答辩时间: 2 0 1 4 年 5 月

学位授予日期: 2 0 1 4 年 6 月

答辩委员会主席: \_\_\_\_\_

评 阅 人: \_\_\_\_\_

2014年 04 月

基于EUS的透镜阵列加工技术与装置实现

常小龙

指导老师

彭云峰

副教授

厦门大学

## 厦门大学学位论文原创性声明

本人呈交的学位论文是本人在导师指导下,独立完成的研究成果。本人在论文写作中参考其他个人或集体已经发表的研究成果,均在文中以适当方式明确标明,并符合法律规范和《厦门大学研究生学术活动规范(试行)》。

另外,该学位论文为( )课题(组)的研究成果,获得( )课题(组)经费或实验室的资助,在( )实验室完成。(请在以上括号内填写课题或课题组负责人或实验室名称,未有此项声明内容的,可以不作特别声明。)

声明人(签名):

年 月 日



## 厦门大学学位论文著作权使用声明

本人同意厦门大学根据《中华人民共和国学位条例暂行实施办法》等规定保留和使用此学位论文，并向主管部门或其指定机构送交学位论文（包括纸质版和电子版），允许学位论文进入厦门大学图书馆及其数据库被查阅、借阅。本人同意厦门大学将学位论文加入全国博士、硕士学位论文共建单位数据库进行检索，将学位论文的标题和摘要汇编出版，采用影印、缩印或者其它方式合理复制学位论文。

本学位论文属于：

1.经厦门大学保密委员会审查核定的保密学位论文，于 年 月 日解密，解密后适用上述授权。

2.不保密，适用上述授权。

（请在以上相应括号内打“√”或填上相应内容。保密学位论文应是已经厦门大学保密委员会审定过的学位论文，未经厦门大学保密委员会审定的学位论文均为公开学位论文。此声明栏不填写的，默认为公开学位论文，均适用上述授权。

声明人（签名）：

年 月 日



## 摘 要

科技的发展带动现代仪器朝着光、机、电一体化的微结构趋势发展,透镜作为一种重要的光学元件在民用和军用工业领域都有着广泛的应用。用于高精密度设备中的透镜不仅要有优越的光学性能,而且也要有微型化和高集成化的结构,因此透镜微结构中的代表——透镜阵列便应运而生。随着对透镜阵列的应用要求不断提高,传统透镜的加工方法已经很难适用于透镜阵列的加工,因此国内外将目光投向了新的超精密加工方法。其中,基于快刀伺服技术(FTS)的复杂微结构加工具有高频响、高定位精度和高加工精度等突出优点,已然成为微车削加工的主流技术之一。目前,国外许多国家已经成功运用该项技术加工出了高精度的透镜阵列元件,相关产品已应用于工业领域,而国内对该技术的研究起步较晚,对于核心基础技术研究匮乏,加工后的产品质量存在明显差距。基于此,本文研究了基于FTS的透镜阵列加工技术及加工装置,主要内容如下:

1.快刀伺服进给机构的设计:首先对快刀伺服进给机构的驱动方式、导向机构进行了选择;接着设计了快刀伺服进给机构的机械结构,并确定了导向机构的基本尺寸;最后通过对柔性铰链的系统仿真设计和校核确定了其最终尺寸,完成了快刀伺服进给机构的整体结构设计。

2.透镜阵列加工方法与加工形貌仿真研究:以典型的四球冠凸透镜阵列为研究对象,结合车削过程中刀具的螺旋式进给运动方式,提出了透镜阵列面形生成原理和坐标计算的方法;对加工中的形貌仿真原理进行了分析,讨论了主要加工参数对加工结果的影响,编写了加工形貌仿真程序来模拟加工过程,通过仿真结果验证了主要加工参数对加工结果的影响。

3.构建了2轴加工实验平台:设计了2轴平台的机械系统并进行了实物加工,设计了基于运动控制器的开放式数控系统,对系统进行了电气设计选型。

4.平台调试及系统实验研究:对加工平台的移动轴和主轴进行了定位精度测试;对快刀伺服进给机构进行了定位精度、重复定位精度、方波响应以及正弦波响应测试;进行了4组加工实验,实验结果验证了整个加工系统的可行性,同时指出了加工平台软硬件提升的方向。

**关键词:** FTS; 形貌仿真; 透镜阵列加工;

厦门大学博硕士学位论文摘要库



## Abstract

Precision technology now develops very quickly. The development of technology requires the integration of the light, machine, electricity, lens as an important optical components into the modern instruments in civil industry and military industry areas. High-precision instruments and equipment requires the lens to have not only superior optical performance but also structure of miniaturization and integration, so lens array, lens microstructure representative, generates. Conventional lens machining methods are difficult to apply to the lens array, so scholars' attention all over the world is devoted to the new ultra-precision machining methods. FTS becomes one of the mainstream technologies in microstructure turning area because of its high frequency response, high accuracy and high precision positioning. Currently, many countries have successfully used the technology to machine the precision lens array, and the technology has also been applied to the industrial sector. While domestic research on this technology started late, and the core foundation technologies had not be yet fully mastered, and products quality is still far lag behind the abroad ones. This paper aims to research the technology and device of lens array with FTS. The main contents are listed as follows:

1. To design of FTS feeding mechanism: Firstly, FTS feeding mechanism drive and guiding mechanism were selected. Then, the mechanical structure of FTS feeding mechanism is designed and the basic dimensions of the guiding mechanism were determined.

2. To research the lens array machining method and topography simulation: This paper took the typical four-ball crown lens array as research subjects, and face-shape generation principle and coordinate calculation method of lens array was proposed taking the tool spiral movement into account. The machining topography simulation principle was analyzed, and the main simulation parameters affecting as to the machining results were discussed. Based on the discussion above, this paper composed machining topography simulation program with MATLAB to prove the parameters affecting.

3. To construct a two-axis machining experimental platform: The experimental platform mechanical system design and processing was completed. The motion controller was proposed basing on open CNC system structure and complete electrical design and component selection.

4. Platform debugging and system experiment study: The positioning accuracy of machining platform moving axis and spindle was tested. The positioning accuracy, repeat positioning accuracy, square wave response and sine wave response were also examined. Four groups machining experiments were implemented and experimental results verified the feasibility of the overall processing system. The upgrade direction of the processing platform hardware and software have been presented.

**Keyword:** FTS; Topography Simulation; Lens Array Machining;

## 目 录

<b>第一章 绪论</b> .....	<b>1</b>
1.1 课题研究的背景和意义.....	1
1.2 实现微结构车削加工的方式.....	2
1.2.1 飞刀切加工.....	2
1.2.2 慢刀伺服加工技术.....	3
1.2.3 快刀伺服加工.....	3
1.2.4 三种加工方式的特点比较.....	4
1.3 基于 FTS 的微结构加工研究现状.....	6
1.4 本文的主要研究内容.....	8
<b>第二章 透镜阵列加工中快刀伺服进给机构的设计与分析</b> .....	<b>11</b>
2.1 透镜阵列加工中快刀伺服进给机构的设计要求.....	11
2.2 快刀伺服进给机构的设计.....	12
2.2.1 快刀伺服进给机构的驱动方式和导向机构选择.....	12
2.2.2 导向机构的材料和加工方式选择.....	15
2.2.3 导向机构的结构形式选择.....	16
2.2.4 快刀伺服进给机构机械结构设计.....	18
2.2.5 导向机构的有限元仿真设计.....	19
2.2.6 导向机构的性能校核.....	25
2.3 本章小结.....	30
<b>第三章 基于 FTS 的透镜阵列加工方法与形貌仿真研究</b> .....	<b>31</b>
3.1 透镜阵列面形生成方法研究.....	31
3.1.1 面形数据生成原理.....	31
3.1.2 面形离散化的坐标计算方法.....	32
3.1.3 数据处理方式的选择.....	34
3.2 透镜阵列微结构加工形貌仿真研究.....	35

3.3.1 形貌仿真原理.....	35
3.3.2 仿真主要参数设置分析.....	38
3.2.3 透镜阵列形貌仿真及主要参数影响分析.....	41
<b>3.3 加工软件规划.....</b>	<b>47</b>
<b>3.4 本章小结.....</b>	<b>48</b>
<b>第四章 透镜阵列加工实验平台构建.....</b>	<b>49</b>
<b>4.1 透镜阵列 2 轴加工实验平台总体方案设计.....</b>	<b>49</b>
<b>4.2 实验平台机械系统设计与部件选型.....</b>	<b>50</b>
4.2.1 实验平台结构形式确定.....	50
4.2.2 精密进给方式设计选型.....	51
4.2.3 精密主轴部件设计选型.....	53
4.2.4 调整机构设计.....	56
4.2.5 其他附属部件设计选型.....	59
4.2.6 加工平台的整体三维结构和实物.....	60
4.2.7 加工平台装配要点.....	61
<b>4.3 实验平台控制系统的硬件及电气设计.....</b>	<b>62</b>
4.3.1 实验平台控制系统总体设计.....	62
4.3.2 控制系统硬件设计.....	63
4.3.3 控制系统电气设计.....	67
<b>4.4 本章小结.....</b>	<b>68</b>
<b>第五章 平台调试及系统实验研究.....</b>	<b>69</b>
<b>5.1 运动平台性能测试.....</b>	<b>69</b>
5.1.1 移动进给轴性能测试.....	69
5.1.2 主轴性能测试.....	69
5.1.3 快刀伺服进给机构性能测试.....	71
<b>5.2 透镜阵列加工实验.....</b>	<b>75</b>
5.2.1 实验条件.....	75
5.2.2 实验参数.....	76

5.2.3 仿真结果.....	77
5.2.4 实验加工.....	77
5.2.5 实验分析.....	82
5.3 本章小结.....	84
<b>第六章 总结与展望.....</b>	<b>85</b>
6.1 总结.....	85
6.2 展望.....	86
参考文献.....	87
致 谢.....	91
硕士期间科研成果.....	92

厦门大学博硕士学位论文摘要库

## Contents

<b>Chapter 1 Introduction.....</b>	<b>1</b>
<b>1.1 Background and Significance of Project.....</b>	<b>1</b>
<b>1.2 Microstructure Machining Methods.....</b>	<b>2</b>
1.2.1 Fly-cutting.....	2
1.2.2 Slow Tool Servo.....	3
1.2.3 Fast Tool Servo.....	3
1.2.4 Comparison of The Three Machining Methods.....	4
<b>1.3 Literature Review on Microstructure Machining with FTS.....</b>	<b>6</b>
<b>1.4 Outline of The Thesis.....</b>	<b>8</b>
<b>Chapter 2 Design and Analysis of FTS Feeding Mechanism in Lens Array Maching.....</b>	<b>11</b>
<b>2.1 Design Requirements of FTS Feeding Mechanism.....</b>	<b>11</b>
<b>2.2 Design of FTS Feeding Mechanism.....</b>	<b>12</b>
2.2.1 Choice of Drive and Guiding Mechanism in FTS Feeding Mechanism.....	12
2.2.2 Choice of Material and Maching Method of Guiding Mechanism.....	15
2.2.3 Choice of Guiding Mechanism Structure.....	16
2.2.4 Mechanical Structure Design of Guiding Mechanism.....	18
2.2.5 FEM Simulation Design of Guiding Mechanism.....	19
2.2.6 Performance Checking of Guiding Mechanism.....	25
<b>2.3 Summary.....</b>	<b>30</b>
<b>Chapter 3 Reserch on Lens Array Machining Method and Topography Simulation with FTS.....</b>	<b>31</b>
<b>3.1 Reserch on Surface-shape GenerationMothod of Lens Array.....</b>	<b>31</b>
3.1.1 Surface-shape Data Generation Principle.....	31

3.1.2 Coordinate Calculation Method on Surface-shape Discretization.....	32
3.1.3 Data Processing Method Choice.....	34
<b>3.2 Machining Simulation on Lens Array Microstructures.....</b>	<b>35</b>
3.3.1 Topography Simulation Principle.....	35
3.3.2 Main Simulation Parameters Analysis.....	38
3.2.3 Topography Simulation of Lens Array and Main Parameters Impact Analysis.....	41
<b>3.3 Maching Software Plan.....</b>	<b>47</b>
<b>3.4 Summary.....</b>	<b>48</b>
<b>Chapter 4 Experimental Platform Constrction of Lens Array Machining.....</b>	<b>49</b>
<b>4.1 2-axis Experiment Platform Overall Program Design of Lens Array     Maching.....</b>	<b>49</b>
<b>4.2 Mechanical System Design and Components Selection of Experimental     Platform.....</b>	<b>50</b>
4.2.1 Structure Design of Experiment Platform.....	50
4.2.2 Precision Feeding Mode Design and Selection.....	51
4.2.3 Precision Spindle Components Design and Selection.....	53
4.2.4 Adjustment Mechanism Design.....	56
4.2.5 Other Ancillary Components Design and Selection.....	59
4.2.6 Overall Three-dimensional and Physical Structure of Experiment Platform .....	60
4.2.7 Assembly Points of Maching Platform.....	61
<b>4.3 Hardware and Electrical Design of Maching Platform Control Systems... 62</b>	<b>62</b>
4.3.1 Overall Design of Maching Platform Control Systems.....	62
4.3.2 Control Systems Hardware Design.....	63
4.3.3 Control Systems Electrical Design.....	67
<b>4.4 Summary.....</b>	<b>68</b>



Degree papers are in the "[Xiamen University Electronic Theses and Dissertations Database](#)". Full texts are available in the following ways:

1. If your library is a CALIS member libraries, please log on <http://etd.calis.edu.cn/> and submit requests online, or consult the interlibrary loan department in your library.
2. For users of non-CALIS member libraries, please mail to [etd@xmu.edu.cn](mailto:etd@xmu.edu.cn) for delivery details.

厦门大学博硕士学位论文摘要库