高通量便携式荧光检测装置的研制与应用

刘佳佳

指导教师　郭祥群　教授

厦门大学

学校编码：10384　　分类号_____密级_____

学号：20520081151657　　UDC_____

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Development and Application of High-throughput and Portable Fluorescence Device

刘佳佳

指导教师姓名：郭祥群 教授

专 业 名 称：分 析 化 学

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LIU JIA-JIA

Supervisor: Prof. GUO XIANGQUN

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摘 要

多通道高通量荧光检测系统因能将批量分析速度提高数倍至数十倍，在药物筛选、医疗诊断、高通量测序、生物作用研究、生态学、实际质检等领域具有重要的实践意义。近年来，具有多通道特点的高通量荧光检测装置的研究取得了重要进展，但是这些装置并没有同时实现小巧轻便、结构简单、灵敏度高、成本低廉、并适用于不同波长物质的检测。因此，本论文设计并构建了一种基于一字线激光模组的高通量便携式荧光检测装置，介绍了该装置的设计、结构、性能以及实用检测效果。论文共分为四章，包括前言、高通量便携式荧光检测装置的研制、高通量便携式荧光检测装置在快速检测水溶液中 Hg^{2+}中的应用及结论与展望。

第一章，前言，通过文献调研，对高通量检测的应用及意义进行了归纳和总结；介绍了近年来高通量检测的分析方法；综述了高通量荧光检测装置的研究现状，并在此基础上提出了论文的研究思路。

第二章，高通量便携式荧光检测装置的研制。本章设计并构建了一种基于一字线激光模组的高通量便携式荧光检测装置，通过选用小型化而灵敏的光源、检测器和光路结构，同时实现装置的小巧轻便、结构简单、灵敏度高、成本低廉、并适用于不同波长物质的多通道检测。结合自行研制的图像处理软件，对 96 孔微孔板样品的检测与数据处理可在 10 min 内完成，实现了溶液的高通量定量检测。检测罗丹明 B 的灵敏度为 2.80 ± 0.15 nmol/L。

第三章，高通量便携式荧光检测装置在快速检测水溶液中 Hg^{2+}的应用。基于罗丹明 B 与纳米金荧光共振能量转移（FRET）的 Hg^{2+}检测方法，应用本装置检测水溶液中 Hg^{2+}浓度，检测限为 7.72 ppb；检测自来水样品中 Hg^{2+}的加标回收率为 99.9 ~ 102.4 %，RSD 为 1.54 ~ 2.57 %；检测湖水样品中 Hg^{2+}的加标回收率为 96.2 ~ 98.9 %，RSD 为 1.60 ~ 2.45 %。本装置有望用于大批量样品的现场快速检测。荧光仪检测该体系的检测限比本装置低 1 个数量级，但本装置检测具有简单、快速、费用低等特点。

第四章，对研究工作做出总结，指出其不足之处，并对该课题的研究前景进行了展望。

关键词：高通量；便携式；荧光检测装置；一字线激光模组

Abstract

Multi-channel and high-throughput fluorescence measuring systems provide a great advantage in speeding up the batch analysis from several-fold to hundred-fold, and would be practically significant in application areas such as pharmaceutical screening, medical diagnosis, high-throughput sequencing, study on biological action, bionomics, actual aquality testing, etc. Recently, the research on the multi-channel and high-throughput fluorescence devices has made great progress. However, they haven't realize portability, simpleness, high-sensitivity, low-cost and application in the detection of matters with different excitation wavelength simultaneously. Herein we report the design and fabrication of a novel high-throughput and portable fluorescence device using a line laser pointer as the light source. The principle, structure, performance and application of the as-constructed device is introduced.

This thesis consists of four chapters.

Chapter 1, Introduction. A brief introduction of the application and significance of high-throughput detection were given. A basic principle of high-throughput detection methodology were introduced. A review discussing the present stage of single-channel and multi-channel high-throughput fluorescence devices was outlined. Based on the update development in these areas, the research plan for the thesis was put forward.

Chapter 2, Development of High-throughput and Portable Fluorescence Device. The design and fabrication of a novel high-throughput and portable fluorescence device using a line laser pointer as the light source was reported. The as-constructed device realizes portability, simpleness, high-sensitivity, low-cost and application in the detection of matters with different excitation wavelength simultaneously by choosing small and sensitive optical assembly and structure. It takes less than 10 min to collect and process data for a 96 microplate-batch analysis of solution samples, by combining use of lab-made software, Chem-Image-Processor (CIP). Its sensitivity

was evaluated with rhodamine B (RB) and the limit of detection (LOD) was 2.80 ± 0.15 nmol/L.

Chapter 3, Application of High-throughput and Portable Fluorescence Device in quick detection of Hg^{2+} in aqueous solution. The new system has been further validated by the detection of Hg^{2+} in aqueous solution based on the modulation effect of Hg^{2+} on the FRET efficiency between RB and TSA@Au, and a LOD of 7.72 ppb was obtained. The standard addition recovery of Hg^{2+} in tap water samples was 99.9 ~ 102.4 % and the RSD was 1.54 ~ 2.57 %. The standard addition recovery of Hg^{2+} in pond water samples was 96.2 ~ 98.9 % and the RSD was 1.60 ~ 2.45 %. It has shown great promise in volume-detection on the spot. The LOD obtained by the as-constructed device was an order of magnitude higher than that obtained by the fluorospectrophotometer, but the detection with the device was simple, quick and low-cost.

Chapter 4, Conclusions and Perspectives. The research work was summarized and the prospect of the research field was given.

Key words: High-throughput; Portable; Fluorescence device; Line laser pointer