Temperature Impact on AHR Spectrometer Optical Bench

Author: Yan JiaBing 嚴佳宾

1 Introduction

In this test, we study the wavelength drift of AHR02 influenced by temperature.

AHR02 cover 190nm-1100nm, it has approximately 1nm resolution with 25um slit.

AHR series spectrometer is optimized to have negligible temperature impact on the wavelength and resolution.

Spectrometer is very sensitive to temperature change. We know that CCDs have higher noise when temperature increases. For example the dark current of CCD sensor is temperature dependent. One can partially remedy this by save the dark current and subtract the dark current from the signal, as long as the signal is above the dark noise. Temperature has strong impact on the optical bench as well on wavelength stability and resolution. When the material expands or shrinks, the wavelength drift and resolution changes. In some designs, the fasteners holding the optics in place lack good elasticity and the wavelength calibration does not return to the initial condition after temperature cycles. The error will accumulate over time and one needs to recalibrate the system after some time.

Every material has thermal expansion characteristic defined as Coefficient of Thermal Expansion (CTE).

Material	Linear CTE (ppm/C)
Aluminum	22.2
Steel Stainless Austenitic (316)	16.0
Epoxy, cast resins & compounds, unfilled	45 – 65
Soda Lime Glass	8.6
Borosilicate Glass	3.3

To summarize the issues:

1. Impact of material CTE on the optical path.
2. Movement of Fastener holding the optical components.
3. Elasticity of the entire system during temperature cycle.

To minimize the temperature dependency, each issue is taken into consideration during the optical design. Numerous experiments were performed to find the optimal solutions. The design is patented.

In this document, we will performance temperature cycle test (10-50C) on three units.

目录

Revision

1. Creation of document 7/16/2014

2 Experiment Procedure

We use environment chamber HZ-2004A Programmable Temperature and Moisture environment chamber made by HengZun Instrument. Spectrometers were wired through the rubber outlet and readings were taken while spectrometers are in the environment chamber.

Temperature cycle range: 10C – 50C

Units under test:

AHR02, 190-1100nm, Serial 02-3616

AHR02, 190-1100nm, Serial 02-3618

AHR03, 190-550nm, Serial 03-3618

Each spectrometer has gone through numerous temperature cycle test before this test.

Temperature is changed 10C per 20min, it is stabilized for 10min at 10C, 20C, 30C, 40C, 50C, and measurement taken at the last minute.

Mercury calibration light is used to study the wavelength drift.

本实验用环境试验机来进行，通过程序对试验机中温度进行控制，控制温度范围为 10℃到 50℃。测试本公司 AHR02（波长范围 190-1100nm）、AHR03（190-550nm）型光谱仪在 10℃到 50℃温度变化时对仪器的影响。该测试中随机选取三台仪器进行测试，分别为 AHR02 型光谱仪序列号 02-3616，AHR02 型光谱仪序列号 02-3618，以及 AHR03 的序列号为 03-3618。

實驗前光譜儀都已經做多次溫度循環。

试验机温度降到 10℃保温时间 10 分钟测量　然后升温 20 分钟升到 20℃保温 10 **分钟测量，每升温 10℃使用时间 20 分钟 保温 10 分钟. 测量在最後一分鐘進行。 试验机温度从 10℃开始上升到 50℃，实验时 10℃到 50℃每隔 10℃保存一次数据，以及仪器在实验前后均保存数据，所保存的数据积为标准汞氩灯谱线。**

2.1 Thermal Wavelength Drift Data from AHR02 02-3616. 光谱仪 02-3616 实验数据分析

表 1　序列号 02-3616 在实验前室温（30℃）下测量汞氩灯波峰及其对应分辨率

Hg-Ar Peaks before Experiment Ambient 30C

Theoretical Peak（nm）	Measured（nm）	Resolution（nm）
253.65	253.66	0.88
296.73	296.75	0.89
404.66	404.66	0.88
435.84	435.85	0.88
546.07	546.07	0.89
576.96	576.94	0.93
579.07	579.05	0.90
763.51	763.52	0.92

以上表格 1 中所列波峰为汞氩灯中的几个重要波峰，下面我们选取其中一部分波峰作为实验测量的数据进行分析。

Table 1 listed the Hg-Ar calibration lamp peaks and resolution before experiment. We will monitor the peak shift during experimentation.

表 2 实验中不同温度下汞氩灯实测波长

Peak wavelength reading at different temperature

Ambient Before (nm)	10℃ (nm)	20℃ (nm)	30℃ (nm)	40℃ (nm)	50℃ (nm)	Ambient After Test (nm)
253.66	253.71	253.69	253.67	253.64	253.60	253.69
404.66	404.71	404.69	404.66	404.64	404.62	404.69
546.07	546.11	546.08	546.07	546.05	546.03	546.10
763.52	763.54	763.54	763.52	763.49	763.49	763.55

表 3　以实验前室温 25℃测量数据为基准，比较实验中谱线波长位置漂动情况

Use reading before the test as reference, we calculate the shifted amount

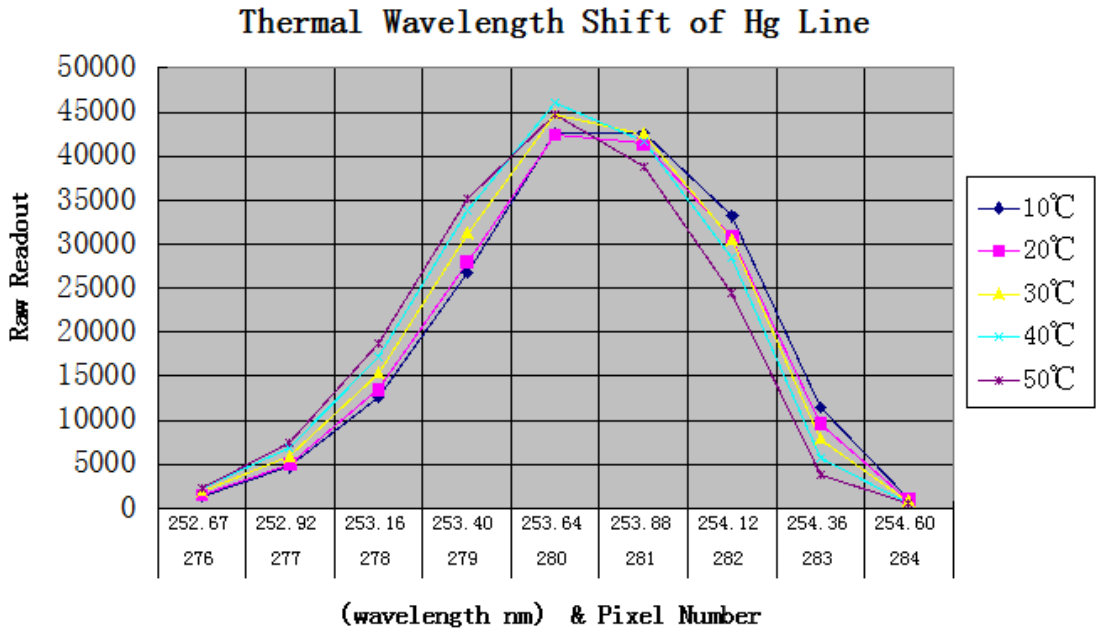
Ambient Before (nm)	10℃ (nm)	20℃ (nm)	30℃ (nm)	40℃ (nm)	50℃ (nm)	Ambient After (nm)
253.66	0.05	0.03	0.01	-0.02	-0.06	0.11
404.66	0.05	0.03	0	-0.02	-0.04	0.09
546.07	0.04	0.01	0	-0.02	-0.04	0.08
763.52	0.02	0.02	0	-0.03	-0.03	0.05

根据以上的数据表明，该仪器温度在 10℃到 50℃下变化，温漂范围在 0.11nm, 即 0.44pixel.

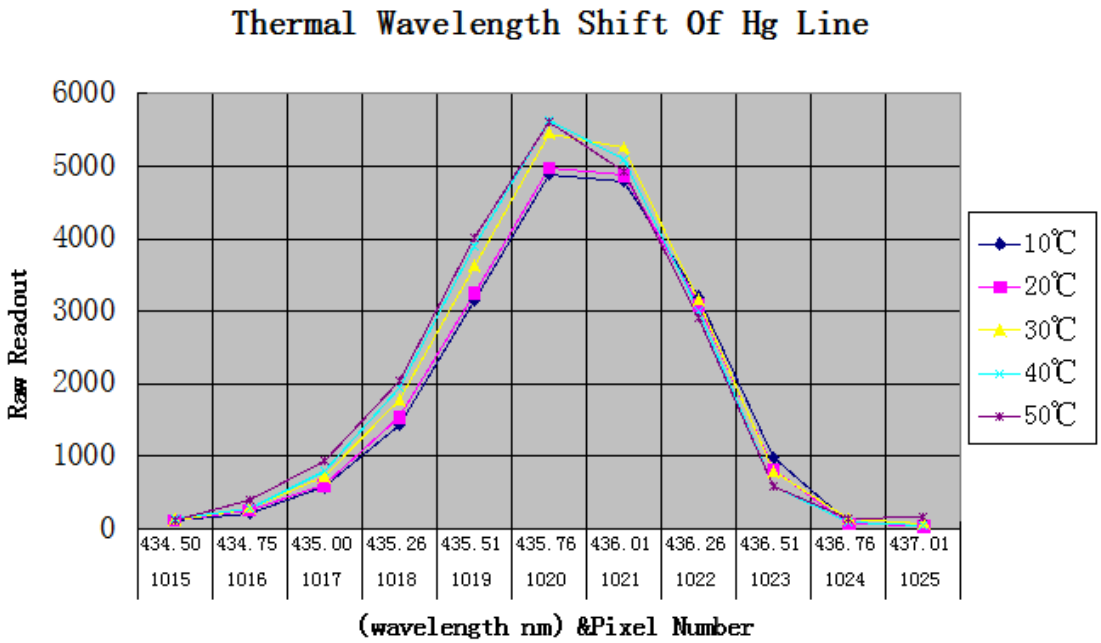
From the above test, the maximum temperature drift from 10C to 50C is 0.11nm, Corresponding to 0.44pixel in TCD1304 with 8um pixel period.

下列图示为各个波峰在 10℃到 50℃之间温度变化，波峰变化实测图：

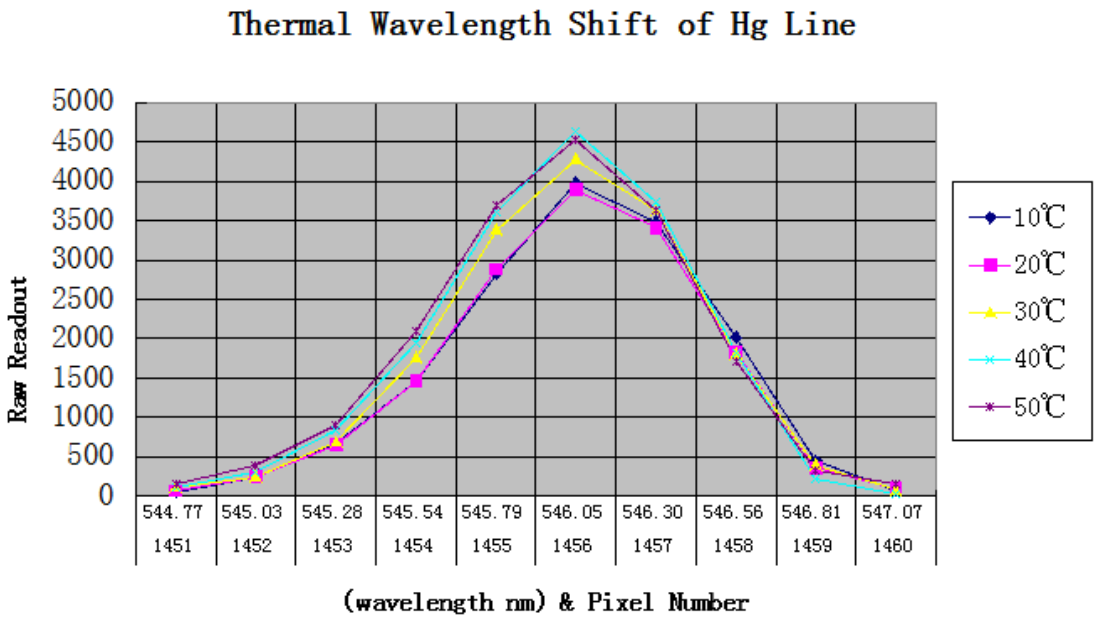
Below is the actual 253.65nm peak recorded at different temperature.



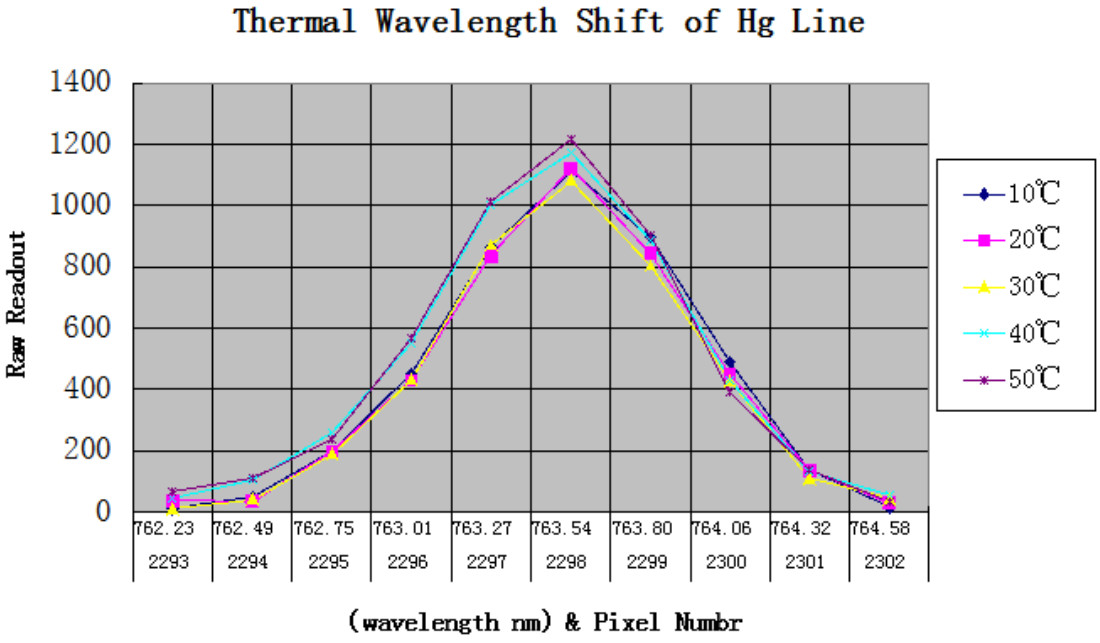
Graph 1 253.72nm Peak



Graph 2 435.84nm Peak



Graph 3 546.07nm Peak



Graph 4 763.52nm Peak

2.2 Thermal Wavelength Drift Data from AHR02 02-3618 Measured Environment Data
光谱仪 02-3618 实验数据分析

表 4 序列号 02-3618 光谱仪在实验前室温（30℃）下测量汞氩灯波峰及其对应分辨率

Hg-Ar Peaks before Experiment Ambient 30C

Theoretical Peak（nm）	Measured（nm）	Resolution（nm）
253.65	253.67	0.88
296.73	296.77	0.90
404.66	404.66	0.92
435.83	435.81	0.93
546.07	546.06	0.90
576.96	576.95	0.90
579.07	579.05	0.89
763.51	763.53	0.81

表 2 实验中不同温度下汞氩灯实测波长

Peak wavelength reading at different temperature

Ambient Before（nm）	10℃（nm）	20℃（nm）	30℃（nm）	40℃（nm）	50℃（nm）	Ambient After（nm）
253.67	253.76	253.73	253.70	253.66	253.63	253.68
435.85	435.91	435.89	435.87	435.84	435.82	435.86
546.09	546.15	546.12	546.10	546.08	546.0	546.11
763.50	763.55	763.52	763.50	763.50	763.49	763.5

表 3 以实验前室温 25℃测量数据为基准，比较实验中谱线波长位置漂动情况

Use reading before the test as reference, we calculate the shifted amount

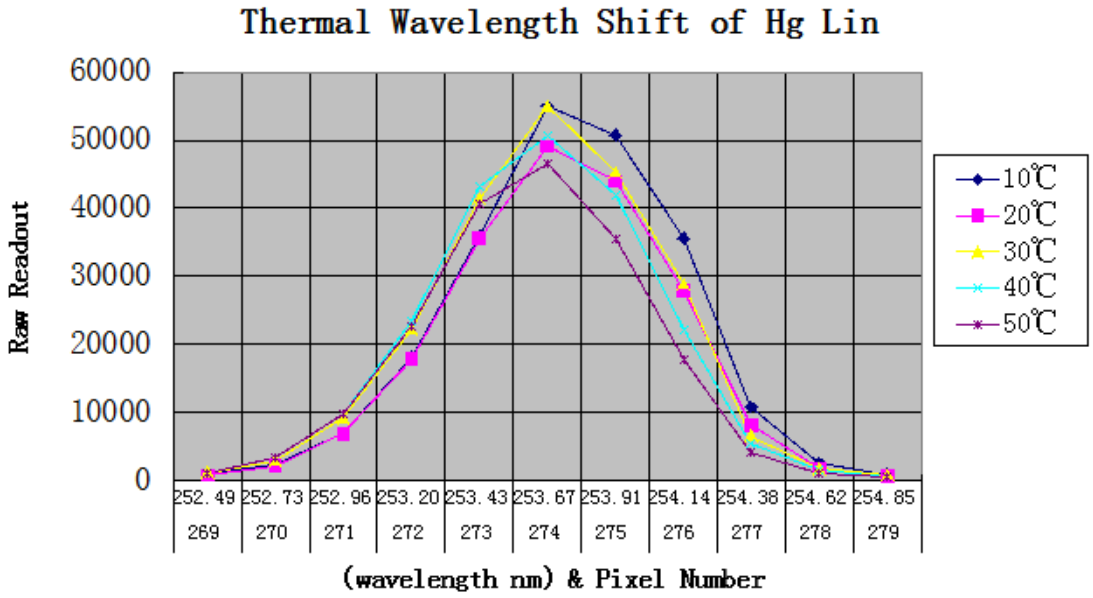
Ambient Before (nm)	10℃ (nm)	20℃ (nm)	30℃ (nm)	40℃ (nm)	50℃ (nm)	Ambient After (nm)
253.67	0.09	0.06	0.03	-0.01	-0.04	0.01
435.85	0.06	0.04	0.02	-0.01	-0.03	0.01
546.09	0.06	0.03	0.01	-0.01	-0.02	0.02
763.5	0.05	0.03	0	0	-0.01	0

根据以上的数据表明，该仪器温度在 10℃到 50℃下变化，温漂范围在 0.13nm, 即 0.51pixel.

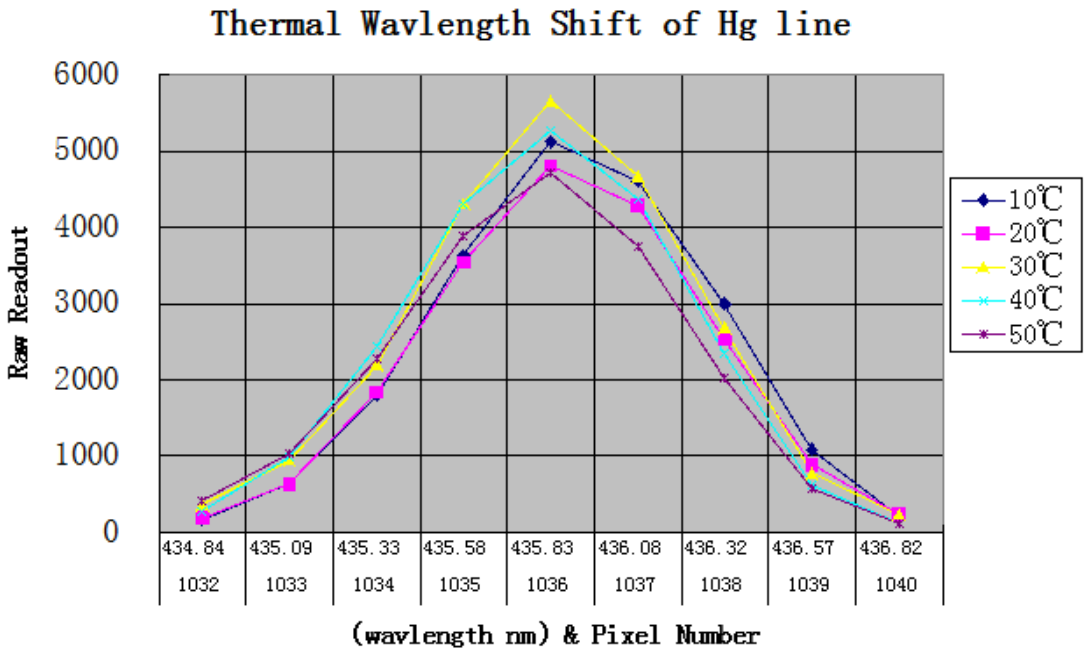
From the above test, the maximum temperature drift from 10C to 50C is 0.13nm, 0.51pixel.

下列图示为各个波峰在 10℃到 50℃之间温度变化，波峰变化实测图：

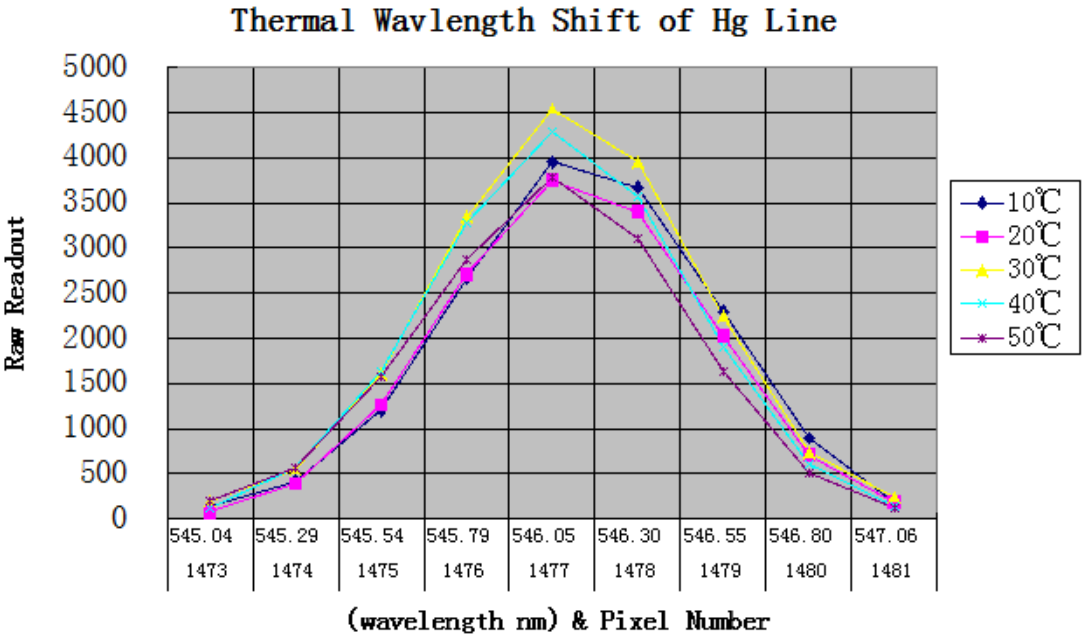
Below is the actual peak recorded at different temperature.



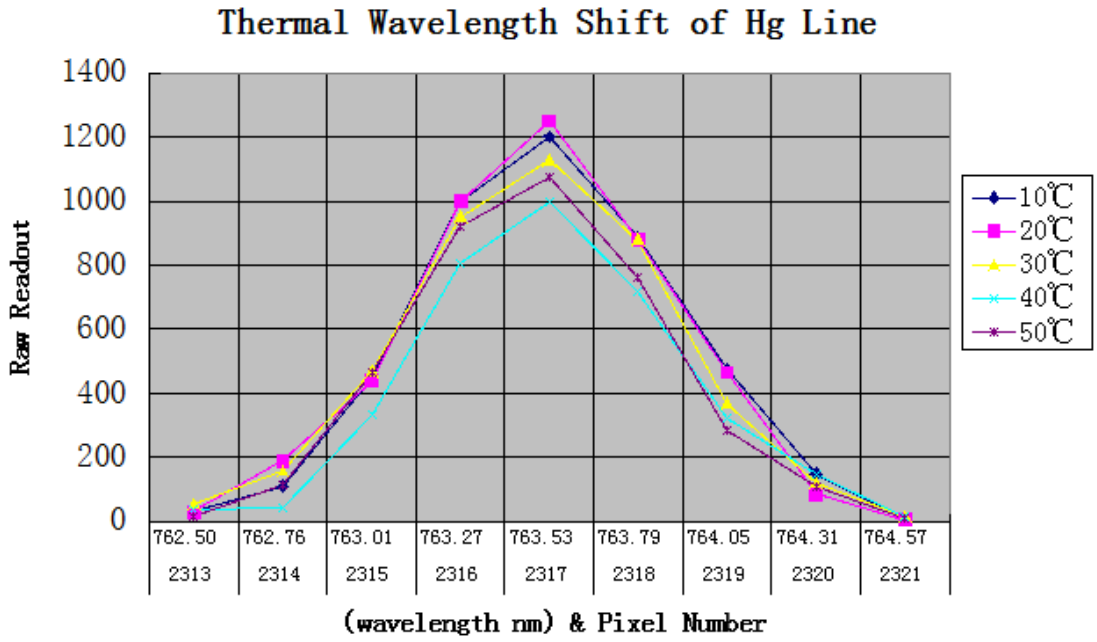
Graph 1 253.72nm Peak



Graph 2 435.84nm Peak



Graph 3 546.07nm Peak



Graph 4 763.52nm Peak

2.3 2 Thermal Wavelength Drift Data from AHR03 03-3618 光谱仪 03-3618 实验数据分析

表 1 序列号 03-3618 在实验前室温（30℃）下测量汞氩灯波峰及其对应分辨率

Hg-Ar Peaks before Experiment Ambient 30C

Theoretical Peak (nm)	Measured (nm)	Resolution (nm)
253.65	253.65	0.38
296.72	296.72	0.36
313.15	313.16	0.35
365.01	365.01	0.35
404.66	404.66	0.35
435.83	435.83	0.36
546.07	546.07	0.49

以上表格 1 中所列波峰为汞氩灯中的几个重要波峰，下面我们选取其中一部分波峰作为实验测量的数据进行分析。

Table 1 listed the Hg-Ar calibration lamp peaks and resolution before experiment. We will monitor the peak shift during experimentation.

表 2 实验中不同温度下汞氩灯实测波长

Peak wavelength reading at different temperature

Ambient Before (nm)	10℃ (nm)	20℃ (nm)	30℃ (nm)	40℃ (nm)	50℃ (nm)	Ambient After (nm)
253.65	253.67	253.67	253.65	253.64	253.62	253.64
296.73	296.75	296.74	296.72	296.71	296.71	296.71
435.83	435.84	435.83	435.83	435.83	435.82	435.83
546.08	546.07	546.06	546.07	546.07	546.08	546.07

表 3　以实验前室温 25℃测量数据为基准，比较实验中谱线波长位置漂动情况

Use reading before the test as reference, we calculate the shifted amount

Ambient Before (nm)	10℃ (nm)	20℃ (nm)	30℃ (nm)	40℃ (nm)	50℃ (nm)	Ambient After (nm)
253.65	0.02	0.02	0	-0.01	-0.03	-0.01
296.73	0.02	0.01	-0.01	-0.02	-0.02	-0.02
435.83	0.01	0	0	0	-0.01	0
546.08	-0.01	-0.02	-0.01	-0.01	0	-0.01

根据以上的数据表明，该仪器温度在 10℃到 50℃下变化，温漂范围在 0.05nm, 即 0.0.51pixel.

From the above test, the maximum temperature drift from 10C to 50C is 0.05nm, 0.51pixel.

下列图示为各个波峰在 10℃到 50℃之间温度变化，波峰变化实测图：

Below is the actual curve recorded at different temperature.

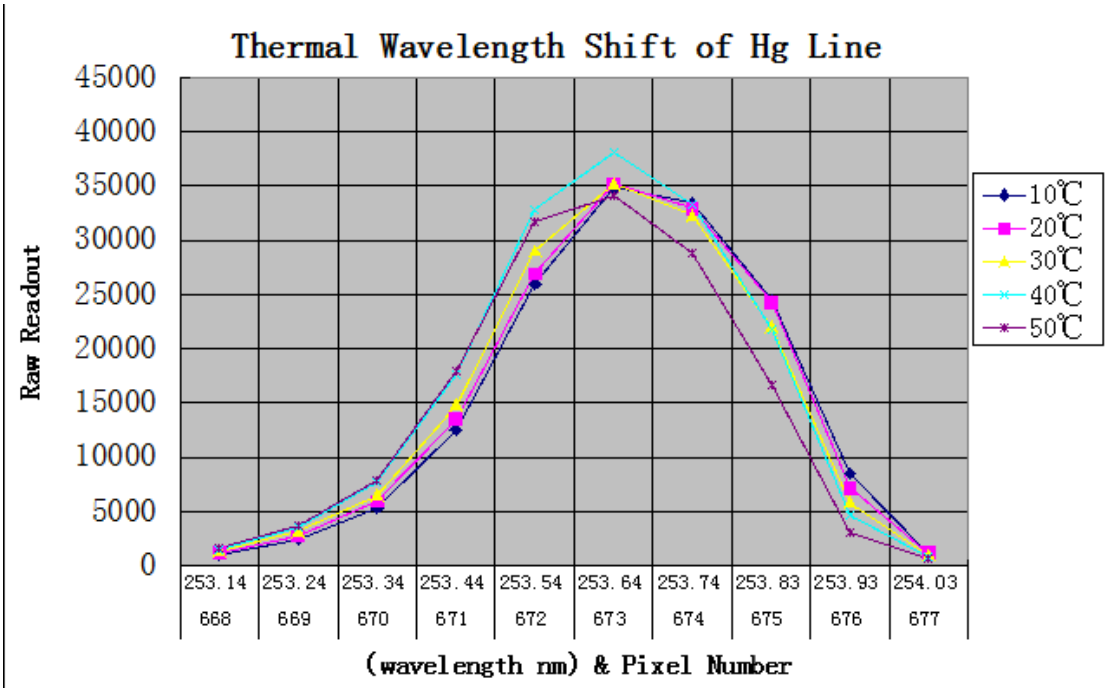
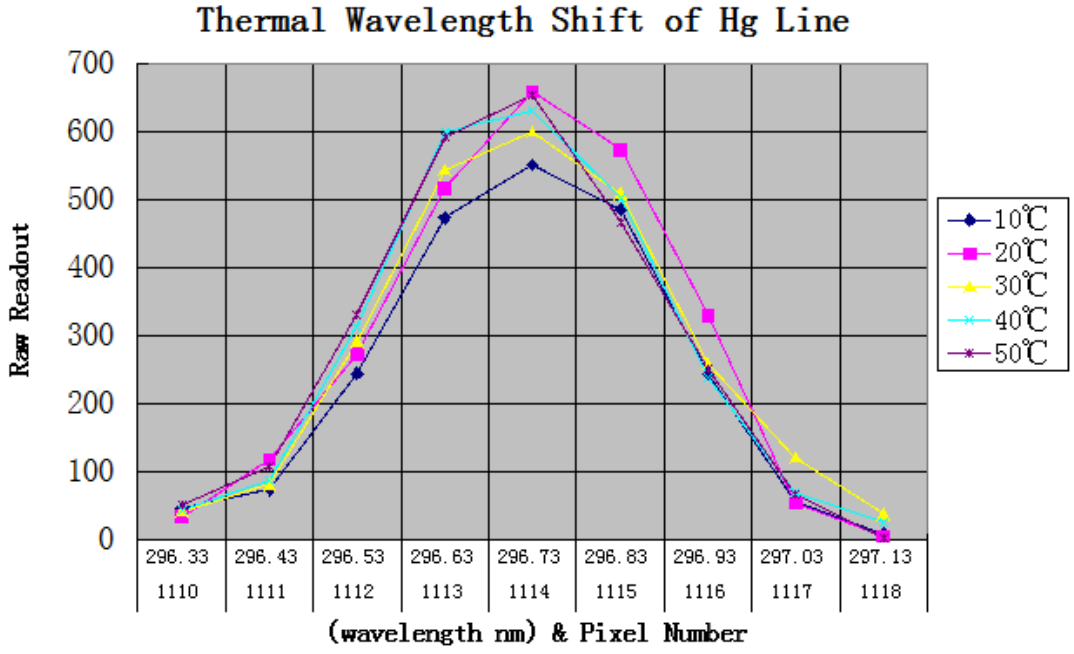
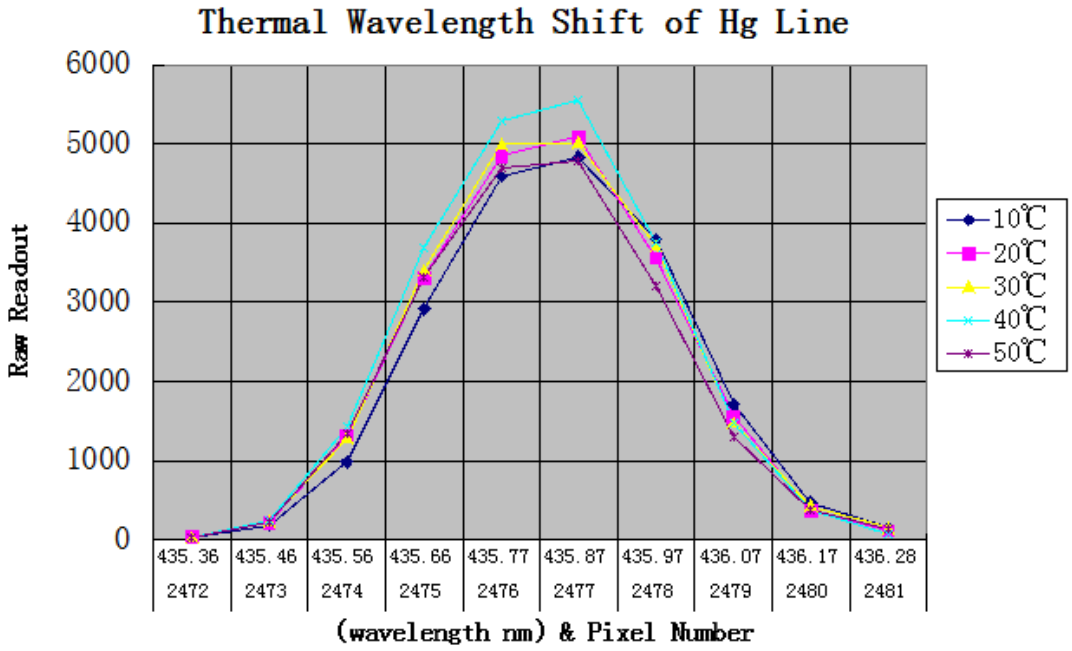


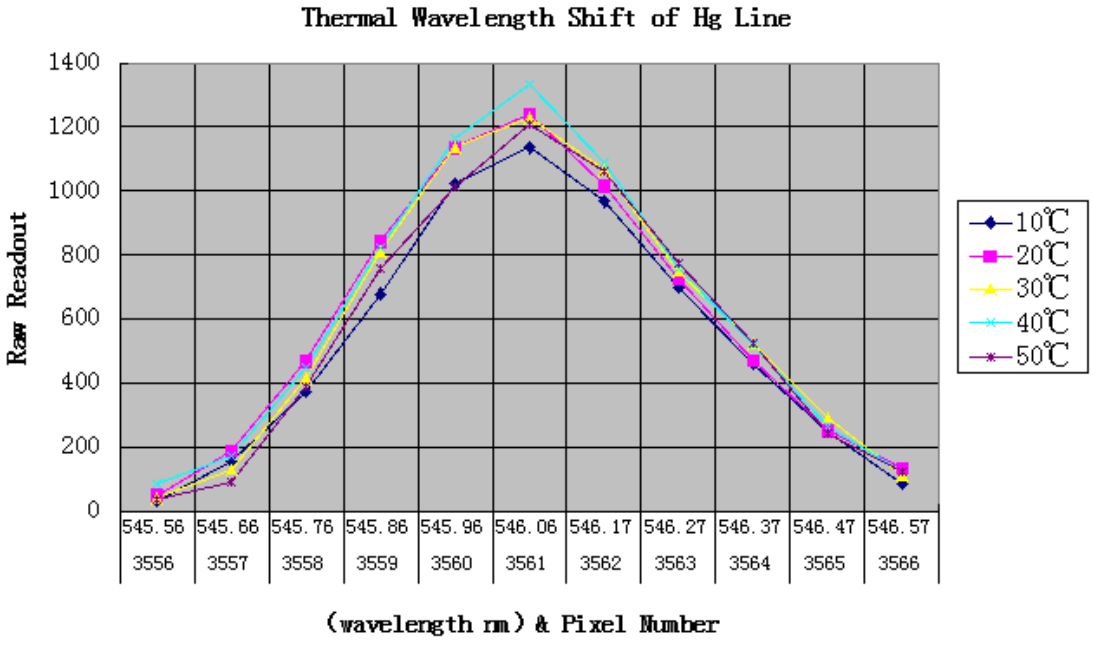
图 1 253.72nm Peak



Graph 2 296.72nm Peak



Graph 3 435.83nm Peak



Graph 4 546.08nm Peak

DISCUSSION

If we only observe the shift of the each point in all the peak profile, we notice zero shift in the horizontal direction but some changes in the Intensity (Y) direction.

There are different ways to measure the horizontal shift. The simplest way is to study the shift of the highest point. In our software, peak is calculated using Gaussian peak curve fitting. If the intensity changes, the peak from numerical approximation can change as well.

The reasons for intensity change:

1. Optical path variation due to CTE. Using our patented technology, the path variation is minimized. It only caused intensity variation but no lateral changes.
2. CCD responsivity vary with the temperature,

The peak intensity profile variation leads to some delta when calculating the peak position using the Gaussian Peak curve fitting numerical algorithm.

CONCLUSION

From the environmental test, we see the wavelength drift is within 0.5pixels for temperature range of 10-40C using Gaussian Peak Fitting algorithm. More accurately, we observed no lateral shift of the spectrum, but only intensity variation.

根据实验后得出的数据进行分析，AHR 系列光谱仪在温度范围为 10℃-50℃之间变化时，波长位置变化量在 0.5pixel 左右（探头总像素 3648pixel），即当仪器所处周围环境温度每变化 1℃，仪器波长精度变化了 0.0125pixel，其實橫向光譜沒有漂移， 光譜強度豎向有變法。 原因為算最高峰是用高斯數學模擬辦法，豎向變化影響到了最高峰位置。 从这里可以看出该系列光谱仪具有非常良好的温度稳定效果，它适用于一些高端仪器、并且对仪器的精度要求较高领域中。